1984

A Rational Expectations Equilibrium Model Of A Small, Specialized Economy

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A RATIONAL EXPECTATIONS EQUILIBRIUM MODEL OF A SMALL, SPECIALIZED ECONOMY

by

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Submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy

Faculty of Graduate Studies
The University of Western Ontario
London, Ontario
November, 1983

ABSTRACT

In this thesis, a rational expectations equilibrium model of the business cycle in a small, open, specialized economy is formulated and tested. The business cycle is as much a fact in small developing economies as in large industrialized ones. Much recent work on business cycles in closed economies and "large" open economies has employed a rational expectations equilibrium framework with incomplete information and this is the approach used in this thesis. The model developed is specifically designed to capture the essential features of small developing economies. The economies modelled here are highly specialized and export oriented, are price takers in international markets, and face volatile and hard to predict terms of trade.

The decision rules of agents are derived from explicit stochastic dynamic optimization problems. As in most formulations of the natural rate hypothesis, much emphasis is placed on uncertainty about relative prices as a source of confusion which helps to generate the cycle. The key relative price about which there is uncertainty is the terms of trade.

The model makes predictions about the behaviour of output. Output is predicted to follow a stochastic difference equation disturbed by unanticipated movements in the terms

of trade and the world price level, as well as by a serially correlated productivity shock. The model also makes predictions about the balance of payments, the price level, and the exchange rate but these are contingent upon the predictions for output being correct.

The predictions of the model for the behaviour of output are tested using data for 13 developing countries in the Caribbean, Central America, Africa, and South-East Asia. The model is also tested against simple Keynesian and classical alternatives. Some, though not complete, support is found for the model. The restrictions of the model are not rejected for most countries. One interesting finding is that real variables outweigh nominal variables in explaining the cycle.

ACKNOWLEDGEMENTS

I should like to thank my Thesis Supervisor, Michael Parkin, and the other members of my Thesis Committee, Peter Howitt and Russell Boyer, for their great assistance in this undertaking. They were a continual source of inspiration and guidance along the way. Special mention must also be made of the contribution of Robin Carter in clarifying certain econometric issues. Helpful comments and criticisms were also proferred by Charles Adams, Kevin Dowd, Jim Frazer, Greg Huffman, Preston Mcafee, Veena Mishra, as well as the participants of the money workshop at The University of Western Ontario. I should also like to thank typist Joanne Lemon for her careful typing of this thesis.

Finally, I should like to express my gratitude to my wife, Jennifer, for her patience, understanding and encouragement during this project.

I bear full responsibility for that which follows.

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INTRODUCTION

The purpose of this thesis is to formulate and test a rational expectations equilibrium model of the business cycle in a small, open specialized economy. There has been a revival of interest in such models since the seminal works of Robert E. Lucas Jr. (1972 and 1973). Lucas sought to explain fluctuations in output and employment as arising from incomplete information about shocks to the economy. In such models, output is modelled as following a stochastically disturbed difference equation. This study was motivated by a desire to model output in small, specialized, developing economies in a similar fashion. The business cycle is as pronounced in such economies as it is in large industrialized ones and it is just as interesting to model the cycle in the developing country as an equilibrium phenomenon.

The model in this thesis owes much to those in Lucas (1973) and Parkin, Bentley and Fader (1981). In addition, the particular specifications of preferences and technology as well as the model solution techniques used are borrowed from Sargent (1979). The Lucas (1973) model explains fluctuations in cyclical output as arising from domestic price level shocks - a short-run Phillips curve. Moreover, the slope of the Phillips curve is predicted to depend on aggregate nominal variance across countries. Thus the model has predictions for both the time series and the cross section. Lucas tested his hypothesis using data from 18 countries and found some limited support. The Lucas model however takes no account of openness and several writers have extended the model to explicitly consider an open economy.

Parkin, Bentley and Fader (1981) and Parkin (1981) derived a Lucas type supply function under fixed and flexible exchange rate regimes with the exchange rate conveying relevant information under flexible rates. In these models, in addition to being shocked by domestic price level surprises, output is shocked by foreign price level and terms of trade surprises. This extension of the Lucas model was tested by Parkin, Bentley and Fader for 21 countries but little support was found either in the time series or the cross section. Other work that has been done in this area includes Leiderman (1979a and b), Burton (1980), Cox (1980), Saidi (1980), Weber (1981), and Kimbrough (1983).

The work which has been done on extending the Lucas model to the open economy has explicitly or implicitly dealt with economies that are large, produce a wide variety of goods with a large proportion of output being consumed domestically. The major contribution of this thesis is in constructing and testing an incomplete information equilibrium model of the business cycle specifically designed to capture some of the essential features of small specialized economies. The economies modelled in this thesis are highly specialized and export oriented and are price takers in international markets. Lucas (1973) models the economy as comprised of a large number of "island" markets. This is a way of generating incomplete information on the part of agents. Parkin, Bentley and Fader also adopt this device in extending the Lucas model to the open economy. The model in this thesis effectively treats the small economy as an individual "island" market set in a larger world economy. This model has rational agents in the small economy attempting to infer their terms of trade in an environment of incomplete information. Agents try to discern relative changes in their own export price from general world price level changes. Incomplete information arises from sequenced decisions within each period. The decision rules of agents are derived from an underlying stochastic dynamic optimization problem with costly adjustment of employment.

Chapter 1 sets out an incomplete information equilibrium model of a small economy. The period structure of the model is described. The representative household maximizes a discounted stream of utility and the representative firm maximizes its net present value. Quadratic objective functions are used in order to obtain linear decision rules and also to obtain a separation of the forecasting and optimization problems. In this chapter the decision rules of households and firms, in particular labour supply and demand, are derived with the nominal wage treated as exogenous.

In Chapter 2, log-linear versions of the decision rules are specified and the equilibrium levels of employment and the nominal wage are obtained. Furthermore, the expected values of variables are calculated as rational expectations on the information sets. By obtaining the solution for equilibrium employment it is then possible to solve for cyclical output. In Chapter 3, the solutions for the balance of payments under a fixed exchange rate and the price level and exchange rate under a flexible exchange rate are derived. These all take as given the output equation from Chapter 2. Chapter 3 also provides a comparison of the effects of the exchange rate regime on the endogenous variables of the model.

Chapter 4 presents the estimates of the coefficients of the output equation for 13 developing countries in the Caribbean, Central America, Africa and South-East Asia.

The predictions of the model of output determination are tested and compared to simple Keynesian and classical (full information) alternatives. The output equation is the only one estimated because it is the major innovation of this study. The equations for the demand for money, the balance of payments, the price level, and the exchange rate differ from the more or less common monetarist or classical specifications only to the extent that the output equation is different. Indeed, the solutions for the balance of payments under a fixed exchange rate and the exchange rate under a flexible exchange rate are very similar to the corresponding monetary approach equations.

The main new predictions are about the behaviour of cyclical output. Cyclical output is predicted to follow a stochastically disturbed first-order difference equation. The model predicts that output will respond positively to foreign price and terms of trade surprises. The size of this response (the inverse of the slope of the Phillips curve) is predicted to depend systematically on the variances of these surprises. The prior expected value of the terms of trade is also predicted to have a positive impact on output. The model has two main sources of persistence. First, cyclical output is predicted to depend positively, with coefficient less than unity, on its once lagged value, arising out of the costs of adjusting employment. Second, there is a serially correlated shock to the production function which gives rise to a serially correlated disturbance in the output equation.

The empirical evidence presented in Chapter 4 provides some limited support for the model on the time series data. The restrictions of the model are not rejected at the 5% level for 10 of the 13 countries. Interestingly, however, a full information or classical model might do as well in many cases.

Summary remarks and suggestions for future work are given in Chapter 5.

CHAPTER 1

THE BASIC MODEL

1.1 AN OVERVIEW

This chapter sets out a rational expectations equilibrium model of a small, open, specialized economy. The model embodies the Phelps (1969)-Friedman (1968) natural rate hypothesis with expectations being formed rationally. The aggregate supply equation that results is an open economy variant of the Lucas (1973) model of the Phillips curve.

There have been several earlier extensions of the Lucas model to the open economy: among these are Leiderman (1979a and b), Burton (1980), Cox (1980), Saidi (1980), Parkin, Bentley and Fader (1981), Weber (1981), and Kimbrough (1983).

The model proposed here differs from these other works in two respects. First, the economy modelled is a price taker in the markets for both exports and imports, and produces a small subset of the world basket of goods. Second, market behaviour is derived explicitly from the decision rules of households that arise from their respective optimization problems.

The economy produces a single good for export and imports another good (or composite good), both at given world market prices. The only store of value is money, which is tantamount to an assumption of zero capital mobility. The assumption of complete specialization is designed to capture a key feature of many less developed economies in which fluctuations in export earnings are key determinants of fluctuations in income.

A key feature of the model is that households and firms lack complete current information about the state of the economy, at the time that employment decisions are made. Decisions within each period are sequenced. At the beginning of each period, households enter into one-period nominal wage contracts with firms. At the end of the period, households then make their consumption and money demand decisions. This means that agents do not know the price of the consumption bundle when employment (and output) decisions are made, although they do know the world market price of their own output. As a result, in a situation similar to that on an individual Lucas "island" market, agents use all available information, including the observed price of their output, to infer the general level of world prices.[1] Thus, agents try to estimate their own terms of trade after having observed the current price of output.

Each period t is divided into two sub-periods: t(0), the beginning of the period, and t(1) the end of the period. Each period t, equilibrium in the labour market is determined at t(0). At t(0), agents have information on the price of output in units of foreign currency, P^*_{xt}, as well as information on all relevant variables up to and including time t-1. Households supply labour on the basis of an expected real wage because the domestic price level (the price of the imported consumption bundle) is unknown at t(0). A similar approach to this was adopted by Cox (1980). At the end of the period, at t(1), employment and output are predetermined and households make their consumption and money demand decisions on the basis of the known price of the consumption bundle P_t.

The intra-period structure of the model is summarized in Table 1. This table holds for the fixed exchange rate case. Terms in parentheses are the relevant variables for the flexible exchange rate case.

Table 1 shows the information available and the sequencing of decisions within each period. The inter-period problem facing agents will now be sketched.

The representative agent faces an intertemporal optimization problem. The household maximizes an infinite

TABLE 1: THE INTRA-PERIOD STRUCTURE OF THE MODEL

Sub-Period	Information	Decision Variables	Outcomes
t(0)	$I_{t(0)} = I_{t-1}, P_{xt} (P^*_{xt})$, W_t, A_t.	Labour supply and demand.	W_t, N_t, Y_t.
t(1)	$I_t = I_{t(0)}, P_t, P^*_t$, $Z_t, D_t(M_t), F_t(S_t)$, Y_t, G_t, N_t.	Consumption and money demand.	$C_t, \frac{M_t}{P_t}$, $F_t(P_t, S_t)$.

I_{t-1} = information on all variables in the model up to and including time t-1.

$I_{t(0)} = I_{t-1}$ plus new information available at t(0), including P_{xt}.

I_t = full information at time t, available at t(1).

P^*_t = the price of the imported consumption bundle in foreign currency terms; the world price level.

Z_t = the terms of trade

P^*_{xt} = the price of the exported good in foreign currency terms; $P^*_{xt} = P^*_t \cdot Z_t$.

S_t = the exchange rate; the domestic currency price of foreign currency.

P_{xt} = the domestic currency price of output; $P_{xt} = P^*_{xt} \cdot S_t$.

P_t = the domestic price level; $P_t = P^*_t \cdot S_t$.

W_t = the nominal wage

N_t = employment

Y_t = output

A_t = a shock to the marginal product of labour

TABLE 1 (cont'd)

C_t = consumption of the imported good

G_t = real government expenditure

D_t = domestic credit

M_t = the money supply

F_t = foreign assets.

stream of utility. It chooses sequences or contingency plans for C_t, M_t/P_t and N_t to maximize

$$(1)\quad E_{0(0)} \sum_{t=0}^{\infty} d^t\, U(C_t, \frac{M_t}{P_t}, N_t)\ , \qquad 0 < d < 1$$

subject to

$$C_t + \frac{M_t}{P_t} \leq \frac{\pi_t}{P_t} + \frac{W_t}{P_t} N_t + \frac{M_{t-1}}{P_t} - H_t,$$

where d is the discount rate, π_t is nominal profit, H_t is the cost of adjusting employment (to be defined later), and U is increasing in consumption and real balances but decreasing in employment. The presence of real balances in the utility function captures the transactions services yielded by money. The costs of adjustment term H_t is subtracted from household income which implies that some income is lost when there is adjustment of employment.[2] These costs are borne by households but they are also reflected in the wage facing firms. $E_{0(0)}$ denotes the conditional expectation at time 0(0) and is therefore based on the information set $I_{0(0)}$. $I_{0(0)}$ is the information available in the first sub-period of period 0. In general, $E_{t(0)}X_t = E(X_t|I_{t(0)})$ and $E_tX_t = E(X_t|I_t)$. It will be convenient for future analysis to denote real income $\pi_t/P_t + W_t/P_t \cdot N_t$ by Q_t, noting that at t(1) Q_t is predetermined.

The representative firm maximizes its net present value[3]:

$$(2) \quad \max_{\{N_t\}_{t=0}^{\infty}} E_{0(0)} \sum_{t=0}^{\infty} d^t \pi_t/P_t .$$

Using the household budget constraint, the economy-wide budget constraints which must hold, at t(1), under both fixed and flexible exchange rates can be characterized. Under a fixed exchange rate, the money stock M_t is backed by foreign assets F_t and domestic credit D_t:

$$(3) \quad M_t = F_t + D_t .$$

Government expenditure is financed by money creation (taxes are ignored for simplicity):

$$(4) \quad P_t G_t = D_t - D_{t-1} .$$

Therefore the economy-wide budget constraint is

$$(5) \quad C_t + G_t + \frac{F_t - F_{t-1}}{P_t} = Q_t - H_t$$

where $Q_t = P_{xt} Y_t / P_t$, which is the same as $\pi_t/P_t + W_t/P_t \cdot N_t$. Equation (5) yields the real balance of payments as the excess of spending over income.[4]

Under a flexible exchange rate regime we have

$$(6) \quad P_t G_t = M_t - M_{t-1}$$

and hence

(7) $C_t + G_t = Q_t - H_t$,

with the exchange rate fluctuating to maintain the balance of payments at zero.

We are now in a position to examine in more detail the optimization problems of firms and households. In Section 1.2 the household's optimization problem is solved for its decision rule. Section 1.3 solves for the firm's decision rule for employment. I shall proceed provisionally under the assumption of a pure fixed exchange rate; $S_t = \bar{S}$ for all t. This assumption is for convenience of exposition and later it is shown that the exchange rate regime is of no consequence for the levels of employment and output. The framework employed and the solution method used are similar to those used by Sargent (1979, pp. 370-388) in describing a classical model of the labour market in a closed economy. Section 1.4 is a summary.

1.2 THE HOUSEHOLD

The representative household faces the problem of choosing contingency plans for C_t, M_t/P_t, and N_t to maximize

$$(8) \quad E_{0(0)} \sum_{t=0}^{\infty} d^t \left[C_t + u_1 Q_t \cdot \frac{M_t}{P_t} - \frac{u_2}{2} \left(\frac{M_t}{P_t}\right)^2 - \frac{u_3}{2} N_t^2\right]$$

subject to

$$C_t + \frac{M_t}{P_t} = \frac{\pi_t}{P_t} + \frac{W_t}{P_t} N_t + \frac{M_{t-1}}{P_t} - \frac{h}{2} (N_t - N_{t-1})^2$$

and given M_{-1}, N_{-1}, where $u_1, u_2, u_3, h > 0$, $u_1/u_2 < 1$, and $0 < d < 1$. The term $\frac{h}{2}(N_t - N_{t-1})^2$ is the quadratic costs of adjusting employment. Notice that the marginal utility of real balances depends positively on Q_t. The utility accruing to the individual household from holding real balances is assumed to depend on the total economy-wide volume of transactions which is given to the individual household.[5] This implies that the representative household's marginal utility of real balances depends positively on real income, Q_t. The particular form of the utility function used exhibits a constant marginal utility of consumption, as well as income, and has the effect of eliminating income effects from labour supply. The money demand function that results will still however depend on income because of the special assumption made about the marginal utility of real balances.

Quadratic utility and adjustment cost functions were assumed for two reasons. First, they enable the household's contingency plans to be described by a system of linear difference equations which are convenient to work with.[6] Secondly, the certainty equivalence property of quadratic objective functions means that the forecasting and optimization problems facing the household can be separated.[7] The presence of quadratic costs of adjusting employment means that it will not be optimal for the household instantaneously to change its labour supply to a new desired level.

Using the budget constraint to substitute for C_t in (8) modifies the problem to one of choosing contingency plans for N_t and M_t/P_t to maximize

$$(9)\quad E_{0(0)} \sum_{t=0}^{\infty} d^t \Big[\frac{\pi_t}{P_t} + \frac{W_t}{P_t} N_t + \frac{M_{t-1}-M_t}{P_t} - \frac{h}{2}(N_t - N_{t-1})^2 + u_1 \cdot Q_t \frac{M_t}{P_t} - \frac{u_2}{2}\left(\frac{M_t}{P_t}\right)^2 - \frac{u_3}{2}(N_t)^2\Big]$$

given M_{-1} and N_{-1}. The household chooses contingency plans for each N_t and M_t/P_t based on the information that will actually be available when N_t and M_t/P_t must actually be set.

The above problem is really a discrete time calculus of variations problem and maximization yields a system of Euler equations:

$$(10)\quad E_{t(0)}\left[\frac{W_t}{P_t} - hN_t + hN_{t-1} - u_3N_t\right] + dhE_{t(0)}[N_{t+1}-N_t] = 0$$

$$t = 0,1,2,\ldots$$

$$(11)\quad -1 + u_1Q_t - u_2\,\frac{M_t}{P_t} + dE_t\,\frac{P_t}{P_{t+1}} = 0$$

$$t = 0,1,2,\ldots$$

Notice that the information set in the Euler operations for N_t is $I_{t(0)}$, which is the information available when the labour supply decision at time t is made. The information set in the Euler equations for real balances however is I_t, which is available at t(1) when each M_t/P_t is decided upon.

The transversality conditions for this problem are

$$(12)\quad \lim_{T\to\infty} E_{T(0)}d^T\left[\frac{W_T}{P_T} - hN_T + hN_{T-1} - u_3N_T\right] = 0$$

$$(13)\quad \lim_{T\to\infty} d^T\left[-1 + u_1Q_T - u_2\,\frac{M_T}{P_T}\right] = 0\ .$$

These conditions are obtained by using the first-order conditions for the final period T of a finite horizon problem, and taking the limit as $T\to\infty$. To satisfy the transversality conditions we could require that all variables involved be covariance stationary. However, a weaker condition, and one that is sufficient, is to require that the sequences $\{N_t\}_{t=0}^{\infty}$, $\{\frac{W_t}{P_t}\}_{t=0}^{\infty}$, $\{Q_t\}_{t=0}^{\infty}$ and

$\{\frac{M_t}{P_t}\}_{t=0}^{\infty}$ be of exponential order < 1/d. A sequence $\{X_t\}_{t=0}^{\infty}$ is said to be of exponential order < 1/d if there exists $K > 0$, $1 \geq r > d$, such that for all t:[8]

$$|E_{t(0)}X_t| < Kr^{-t} .$$

To see that this assumption is sufficient consider the transversality condition for real balances. Notice that

$$|d^T[-1 + u_1Q_T - u_2 \frac{M_T}{P_T}]|$$

$$\leq -d^T + d^Tu_1|Q_T| - d^Tu_2|\frac{M_T}{P_T}|$$

$$\leq -d^T + d^Tu_1Kr^{-T} - d^Tu_2Kr^{-T}$$

$$= -d^T + u_1K(\frac{d}{r})^T - u_2K(\frac{d}{r})^T .$$

Since $d/r < 1$ we have that the limit as $T\to\infty$ of every term in the last line is zero.

The Euler equations for employment may be written as a system of second-order linear stochastic difference equations:

$$(14) \quad E_{t(0)}N_{t+1} - [\frac{1+d}{d} + \frac{u_3}{dh}]N_t + \frac{1}{d}N_{t-1} = -(dh)^{-1}E_{t(0)}\frac{W_t}{P_t}$$

$$t = 0,1,2,\ldots .$$

This equation relates the current labour supply of the household to once-lagged employment, expected future employment and the expected real wage in terms of the price of the consumption bundle. The Euler equation for real balances yields the demand for money function:

$$(15) \quad \frac{M_t}{P_t} = \frac{-1}{u_2} + \frac{u_1}{u_2} Q_t + \frac{d}{u_2} E_t\left(\frac{P_t}{P_{t+1}}\right) \qquad , \qquad t = 0,1,2,\ldots .$$

That is, the demand for real balances is positively related (with coefficient less than unity) to real income Q_t and negatively related to expected inflation. The consumption equation implied by (15) and the household budget constraint is

$$(16) \quad C_t = \frac{1}{u_2} + \left(1 - \frac{u_1}{u_2}\right) Q_t - \frac{d}{u_2} E_t\left(\frac{P_t}{P_{t+1}}\right) - H_t + \frac{M_{t-1}}{P_t}$$

which relates C_t positively to real income, expected inflation and money balances carried over from previous period. Expected inflation reduces saving and increases current consumption.

1.3 THE FIRM

The representative firm produces a single good using labour. The unmodelled capital stock is assumed to follow a log-linear trend. It is assumed that there are enough firms so that each individual firm treats the wage rate as a given variable. The representative firm's production function is specified to be

$$(17) \quad F(N_t) = (f_0 + A_t)N_t - \frac{f_1}{2} N_t^2 + A_0 e^{a_1 t}$$

where f_0, $f_1 > 0$, and A_t is a shock to the marginal product of labour. A quadratic technology is assumed for the same reasons as before.

At time 0, the representative firm maximizes

$$(18) \quad E_{0(0)} \sum_{t=0}^{\infty} d^t [P_{xt}(f_0+A_t)N_t - P_{xt} \frac{f_1}{2} N_t^2 + P_{xt} A_0 e^{a_1 t} - W_t N_t]/P_t .$$

The firm chooses a sequence $\{N_t\}_{t=0}^{\infty}$, given the exogenous stochastic sequences $\{W_t\}_{t=0}^{\infty}$, $\{P_{xt}\}_{t=0}^{\infty}$ and $\{A_t\}_{t=0}^{\infty}$. That is, the firm chooses a contingency plan for each N_t based on the information that will actually be available when each N_t must be set. The first-order condition is

$$(19) \quad P_{xt}(f_0+A_t) - P_{xt} f_1 N_t - W_t = 0 \qquad t = 0,1,2,\ldots$$

which yields the labour demand schedule:

$$(20) \quad N_t = \frac{f_0}{f_1} + \frac{1}{f_1} (A_t - \frac{W_t}{P_{xt}}) .$$

Equation (20) relates the labour demanded by the firm negatively to the real wage in terms of the price of output, and positively to the technology variable.[9]

1.4 SUMMARY

The model has now been solved for the decision rules of firms and households. The decision rules for labour demand, labour supply, money demand and consumption demand have been obtained. These were derived in the context of a representative household maximizing a discounted stream of utility and a representative firm maximizing its net present value. Therefore, since the domestic labour market (and implicitly, the international commodity market) is assumed to be competitive, the nominal wage was treated as exogenous.

In Chapter 2 equilibrium in the labour market is determined. The equilibrium level of employment is solved for, and so is the equilibrium nominal wage. The viewpoint is of the market and not the individual agents and the nominal wage is now an endogenous variable to be determined by market forces. Given the equilibrium level of employment it is then possible to obtain the solution for output. A major change adopted in Chapter 2 is a log-linearization of the decision rules, equations (14), (15), (16) and (20). This simplifies the solution of the model considerably and facilitates solving for output in an estimable form.

In Chapter 2 also, the hypothesis of rational expectations will be explicitly implemented in the calculation of expectations. Because the model in Chapter 2 is linear and the disturbances are normally distributed, the rational expectations are calculated as linear least squares projections on the information sets.[10]

CHAPTER 1 - FOOTNOTES

1. The resemblance of the economy modelled here to our individual Lucas "island" market does not mean that the informational setup is the same. On a Lucas "island", only a market specific price is observed while in the economies modelled here, both the specific price, that of output, and the general price, that of the imported consumption bundle, are observed. A sequencing arrangement seems to be one convenient way of generating uncertainty about relative prices.

2. There is a substantial literature on adjustment costs. An important reference here is Brechling (1975). A very similar approach to mine is adopted by Sargent (1979, p. 371) in constructing a classical model of the labour market. Sargent has adjustment costs being borne by households as well as firms. I could just as easily have placed the adjustment costs in the utility function. The resultant labour supply equation would be unchanged. I did not follow the more usual procedure of placing the adjustment costs in the production function, or as a cost to the firm, because a non-linear second-order difference equation in labour demand would have resulted.

3. Notice that the firm uses the same discount rate d in

2.2 LABOUR MARKET EQUILIBRIUM

Supply and demand equations for employment have been derived. These are contingency plans giving labour supply at time t as a function of the expected labour supply at t+1, actual employment at t-1, and the nominal wage deflated by the expectation of the domestic price level at time t; and relating labour demand at time t to the nominal wage deflated by the output price, and the technology shock at time t.

The labour market is assumed to clear at each time t(0). The labour market equilibrium is found by solving equations (21) and (22) for the nominal wage and employment. Therefore an equilibrium is a stochastic process for the nominal wage $\{w_t\}_{t=0}^{\infty}$ such that the household is always on its supply schedule (21), the firm is always on its demand schedule (22), and the supply of labour equals the demand for labour at each time t.

To construct an equilibrium, write the firm's decision rule as

$$(27) \quad w_t = -\frac{n_t}{g_1} + a_t + p_{xt} ,$$

and using this to eliminate the nominal wage from (21) yields:

I adopted the device of having the marginal utility of real balances depend positively on economy-wide income. This allows me to trace, in Chapter 3, the effects of the behaviour of output on the other, though less important, endogenous variables such as the balance of payments, the price level, and the exchange rate.

6. Note that a more general quadratic utility function would have the marginal utility of consumption equal to $u_o > 0$ rather than 1. However, the utility function is unique up to a monotonic transformation (dividing through by u_o). A more general form yet would have a marginal utility of consumption that diminishes as consumption gets larger. This would have the effect of introducing income effects on labour supply which I want to avoid. The assumption of a constant marginal utility of consumption also ensures us of linear decision rules. That is, in this case, a general quadratic objective function is not enough to guarantee linear decision rules. This utility function obviously maintains a number of quite restrictive assumptions, most of which seem to be necessary to obtain a Lucas-style supply function.

7. A good discussion of certainty equivalence is given in Lucas and Sargent (1981). This property of quadratic objective functions is also discussed in Sargent (1979, p. 338).

8. This definition is taken from Sargent (1979, p. 335). See page 197 of Sargent for a proof that this ensures satisfaction of the transversality condition for N_t. See also Hansen and Sargent (1980). It was pointed out to me by Greg Huffman that an additional, stronger condition is needed to prevent the utility function from going to $-\infty$. It is required that the processes be of exponential order $< 1/\sqrt{d}$.

9. Note that this ignores Jensen's inequality. This result is true only under a pure fixed exchange rate regime. If the exchange rate is flexible then P_{xt} is unknown at t(0), even though P^*_{xt} is known. In this case, the labour demand schedule could be written

$$N_t = \frac{f_o}{f_1} + \frac{1}{f_1} (A_t + E_{t(0)} \frac{W_t}{P_{xt}}).$$

10. See Sargent (1979, pp. 338 and 339) for a discussion of this.

CHAPTER 2

LABOUR MARKET EQUILIBRIUM AND OUTPUT DETERMINATION

2.1 INTRODUCTION

In this chapter a log-linear version of the model is adopted, processes for the exogenous variables are specified, and the equilibrium levels of employment, the nominal wage, and output are solved for. The log-linear transformation has no justification besides that of convenience and the desire to obtain a solution. Without this transformation, we are faced with a non-linear difference equation describing equilibrium employment, which is difficult to solve. All variables are now in logarithmic terms unless stated otherwise.

Based on the household's contingency plan for employment, equation (14), a version that is linear in the logarithms is postulated:

$$(21) \quad E_{t(0)}n_{t+1} - k_1 n_t + k_2 n_{t-1} = -b_1 E_{t(0)}(w_t - p_t)$$

where

$$k_1 = [\frac{1+d}{d} + \frac{u_3}{dh}] \;,\; k_2 = \frac{1}{d} \;,\; b_1 > 0,$$

and n_t is employment, w_t is the nominal wage, and p_t is the domestic price level. Based on equation (20), a log-linear version of the firm's employment decision rule may be written as

$$(22) \quad n_t = -g_1(w_t - p_{xt} - a_t) \;, \quad g_1 > 0 \;,$$

where p_{xt} is the price of output in domestic currency terms and a_t is the technology variable.

By way of proceeding towards a solution of the model, it is necessary to specify processes for the exogenous variables p^*_t, z_t, p^*_{xt} and a_t. The price of output in foreign currency terms, p^*_{xt}, is given by

$$(23) \quad p^*_{xt} \equiv p^*_t + z_t$$

where it is assumed that the foreign price level p^*_t and the terms of trade z_t are distributed independently of each other. The processes for the exogenous variables p^*_t, z_t and a_t are those revealed by the data (see Chapter 4)[2]:

$$(24) \quad p^*_t - p^*_{t-1} = \nu_0 + \nu_1(p^*_{t-1} - p^*_{t-2}) + v_t \;, \quad 0 < \nu_1 < 1,$$

$$(25) \quad z_t = \delta_0 + \delta_1 z_{t-1} + x_t \;, \quad 0 < \delta_1 < 1,$$

$$(26) \quad a_t = \rho\, a_{t-1} + u_t \;, \quad |\rho| < 1.$$

The random disturbances v_t, x_t and u_t are assumed to be independently distributed normal variates, each with zero mean. Hence

$$v_t \sim N(0,\sigma_v^2) \; , \; x_t \sim N(0,\sigma_x^2) \; , \; u_t \sim N(0,\sigma_u^2)$$

and

$$E(v_t,x_t) = E(v_t,u_t) = E(x_t,u_t) = 0.$$

The domestic price level p_t and the domestic currency price of output p_{xt} are, as defined in Chapter 1,

$$p_t = p_t^* + s_t$$

$$p_{xt} = p_{xt}^* + s_t \; ,$$

where s_t is the exchange rate. The assumption that the exchange rate is fixed at $\bar{s}$ will be made provisionally.

Given that p_t^*, z_t and a_t follow univariate normal stochastic processes, the conditional mathematical expectations are linear and will equal least squares projections. This is used in section 2.2 where the equilibrium in the labour market is calculated. In section 2.3, the solution for output is derived and in section 2.4, the solutions for output and employment are shown to be invariant with respect to the exchange rate regime. Section 2.5 is a summary.

2.2 LABOUR MARKET EQUILIBRIUM

Supply and demand equations for employment have been derived. These are contingency plans giving labour supply at time t as a function of the expected labour supply at t+1, actual employment at t-1, and the nominal wage deflated by the expectation of the domestic price level at time t; and relating labour demand at time t to the nominal wage deflated by the output price, and the technology shock at time t.

The labour market is assumed to clear at each time t(0). The labour market equilibrium is found by solving equations (21) and (22) for the nominal wage and employment. Therefore an equilibrium is a stochastic process for the nominal wage $\{w_t\}_{t=0}^{\infty}$ such that the household is always on its supply schedule (21), the firm is always on its demand schedule (22), and the supply of labour equals the demand for labour at each time t.

To construct an equilibrium, write the firm's decision rule as

$$(27) \quad w_t = -\frac{n_t}{g_1} + a_t + p_{xt} ,$$

and using this to eliminate the nominal wage from (21) yields:

$$(28) \quad E_{t(0)}n_{t+1} - [k_1 + \frac{b_1}{g_1}]n_t + k_2 n_{t-1} = -b_1 E_{t(0)}[p_{xt} - p_t + a_t].$$

We now have a second-order stochastic difference equation describing equilibrium employment over time. It is now necessary to solve for equilibrium employment in terms of observables only. That is, we need to calculate $E_{t(0)}n_{t+1}$ and $E_{t(0)}(p_{xt}-p_t) = E_{t(0)}z_t$ in terms of observables. Actually, solution of the difference equation (28) does the former.

By way of proceeding towards a solution, lag equation (28) once to give

$$(29) \quad E_{t-1(0)}n_t - [k_1 + \frac{b_1}{g_1}]n_{t-1} + k_2 n_{t-2}$$

$$= b_1 E_{t-1(0)}[z_{t-1} + a_{t-1}]$$

or

$$(30) \quad [1 - [k_1 + \frac{b_1}{g_1}]B + k_2 B^2]E_{t-1(0)}n_t$$

$$= -b_1 E_{t-1(0)}[z_{t-1} + a_{t-1}]$$

where the operator B is defined by

$$B^i E_{t(0)}x_t = E_{t(0)}x_{t-i} \, .$$

Therefore the operator B lags or leads the variable x_t but leaves the information set unchanged.

The characteristic equation is

$$(31)\quad [1 - [k_1 + \frac{b_1}{g_1}]B + k_2B^2] = (1-\lambda_1B)(1-\lambda_2B) = 0$$

where $1/\lambda_1$ and $1/\lambda_2$ are the roots. Now $(1-\lambda_1B)(1-\lambda_2B)$ $= 1 - (\lambda_1+\lambda_2)B + \lambda_1\lambda_2B^2$ and by equating powers of B we know that

$$\lambda_1\lambda_2 = \frac{1}{d}$$

$$-(\lambda_1+\lambda_2) = -\Phi$$

$$\text{where}\quad \Phi = \frac{1+d}{d} + \frac{u_3}{dh} + \frac{b_1}{g_1}.$$

Now $\lambda_2 = d^{-1}\lambda_1^{-1}$ and thus

$$(32)\quad d\Phi = \lambda d + \frac{1}{\lambda}.$$

Using equation (32) we can easily locate λ_1 and λ_2.[3] Without loss of generality, allow λ_1 to be the smaller root. Figure 1 illustrates the determination of λ_1 and λ_2 from equation (32). The function $d\lambda + \lambda^{-1}$ reaches a minimum at $\lambda = \sqrt{1/d}$. Now set $u_3 = b_1 = 0$ to give

$$(33)\quad (1+d) = \lambda d + \lambda^{-1}$$

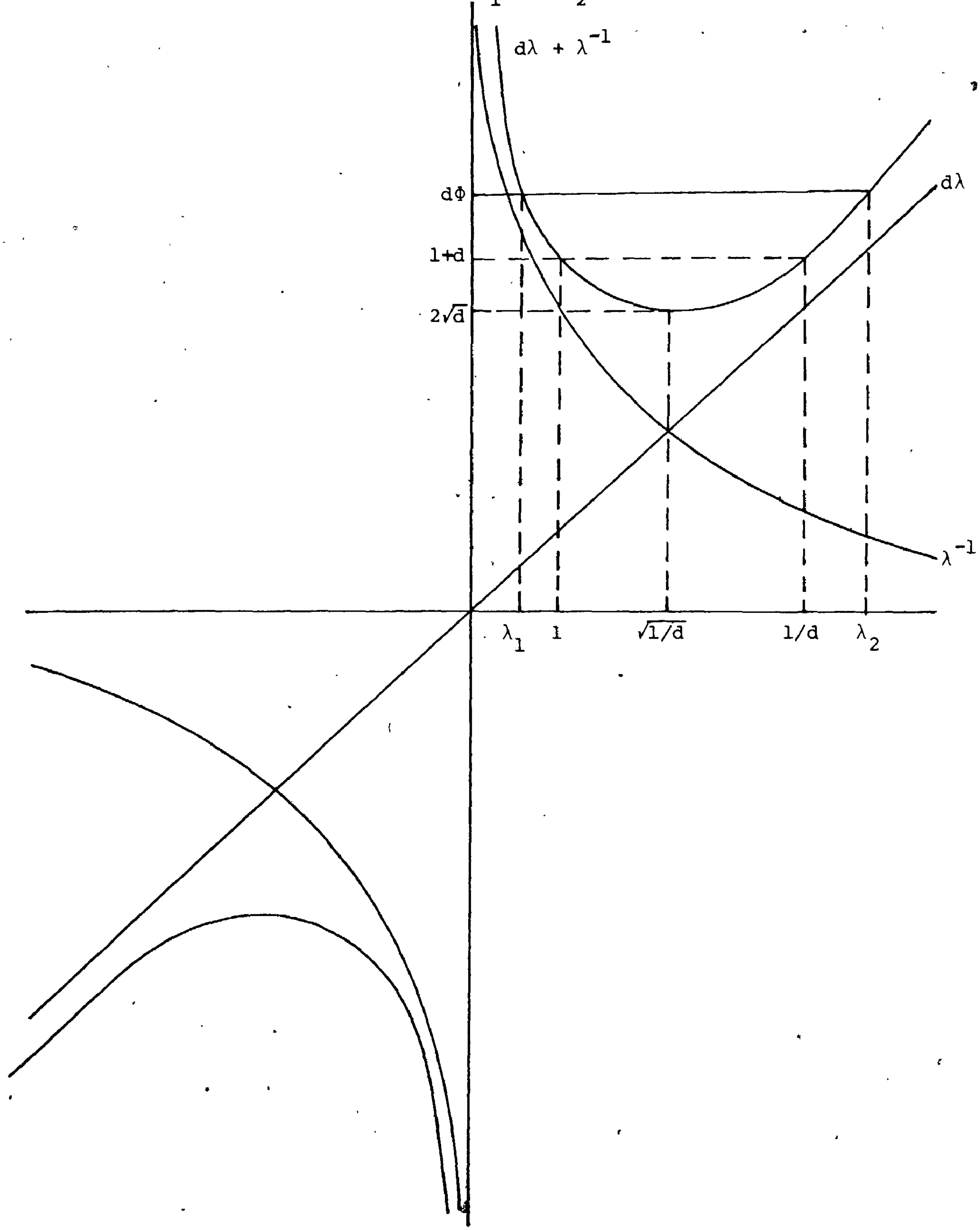
or

$$(34)\quad d\lambda^2 - (1+d)\lambda + 1 = 0,$$

which factors into

FIGURE 1

THE DETERMINATION OF λ_1 AND λ_2



(35) $(1-\lambda d)(1-\lambda) = 0$.

Since $(1+d) > 2\sqrt{d}$ which is the value of $\lambda d + \lambda^{-1}$ at the minimum, we are assured of real and distinct roots. Equation (35) tells us that at $d\Phi = (1+d)$, $\lambda_1 = 1$ and $\lambda_2 = d^{-1}$. But in general we know that $u_3, b_1 > 0$ and hence that

$$0 < \lambda_1 < 1 < 1/d < \lambda_2 .$$

To satisfy the transversality condition[4] solve the unstable root λ_2 forward to obtain

$$(36) \quad (1-\lambda_1 B)E_{t-1(0)}n_t = \frac{b_1\lambda_2^{-1}B^{-1}}{(1-\lambda_2^{-1}B^{-1})}E_{t-1(0)}(z_{t-1} + a_{t-1}) + D_2\lambda_2^t ,$$

where D_2 is set to zero to ensure stability. Equation (36) becomes

$$(37) \quad (1-\lambda_1 B)E_{t(0)}n_t = b_1\lambda_2^{-1} \sum_{i=0}^{\infty} \lambda_2^{-i}E_{t(0)}(z_{t+i} + a_{t+i})$$

where the information set has been updated from $I_{t-1(0)}$ to $I_{t(0)}$, the set actually available when n_t is chosen. Next, since $E_{t(0)}n_t = n_t$ and $E_{t(0)}n_{t-1} = n_{t-1}$, we arrive at

$$(38) \quad n_t = \lambda_1 n_{t-1} + b_1\lambda_2^{-1} \sum_{i=0}^{\infty} \lambda_2^{-i} E_{t(0)}(z_{t+i} + a_{t+i}) .$$

This last equation relates the equilibrium level of employment to once lagged employment, with coefficient less than unity, and to current and all expected future values of $z_t + a_t$.

All that now remains is to calculate the rational expectations of $z_{t+i} + a_{t+i}$, $i = 0,1,2,\ldots$ based on information set $I_{t(0)}$. The expectation of z_t is calculated as a recursive projection because the information set $I_{t(0)}$ contains past information I_{t-1}, plus new information, p_{xt}, observed at t(0). Thus,

$$(39) \quad E(z_t|I_{t(0)}) = E(z_t|I_{t-1}) + E(z_t - E(z_t|I_{t-1})|p_{xt} - E(p_{xt}|I_{t-1})).$$

This formula decomposes the expectation of z_t based on $I_{t(0)}$ into a prior expectation based on I_{t-1} and a revision based on the fact that agents observe the current price of output[5] p_{xt}.

Now $E(z_t|I_{t-1}) = \delta_0 + \delta_1 z_{t-1}$ which means that

$$z_t - E_{t-1}z_t = x_t .$$

Also, $E(p_{xt}|I_{t-1}) = \nu_0 + p^*_{t-1} + \nu_1(p^*_{t-1} - p^*_{t-2})$

$$+ \delta_0 + \delta_1 z_{t-1} + \bar{s}$$

which means that

$$p_{xt} - E_{t-1}p_{xt} = v_t + x_t \; .$$

Substitution of these equations into (39) means that the recursive projection formula becomes

$$(40) \quad E_{t(0)}z_t = \delta_0 + \delta_1 z_{t-1} + E(x_t | x_t + v_t) \; ,$$

which is equal to

$$(41) \quad E_{t(0)}z_t = \delta_0 + \delta_1 z_{t-1} + \frac{\sigma_x^2}{\sigma_v^2+\sigma_x^2}(v_t + x_t) \; .$$

Equation (41) states that the amount by which agents revise their prior expectation of z_t depends on the ratio of the real variance to the sum of nominal and real variances. Given (41), and the fact that $E_{t(0)}x_{t+i} = 0$, $i = 1,2,3,...$, it follows that

$$(42) \quad E_{t(0)}z_{t+i} = \delta_0 + \delta_1^i[\delta_0 + \delta_1 z_{t-1} + \theta(v_t + x_t)] \qquad i = 1,2,3,...$$

where $\theta = \dfrac{\sigma_x^2}{\sigma_v^2+\sigma_x^2}$.

Furthermore, it follows from the process for a_t that

$$(43) \quad E_{t(0)}a_{t+i} = \rho^i a_t \; ,$$

since $E_{t(0)}u_{t+i} = 0$, $i = 1,2,3,...$.

Substituting equations (42) and (43) into equation

(38) yields

$$(44)\quad n_t = b_1\lambda_2^{-2}(1-\lambda_2^{-1})^{-1}\delta_0 + b_1\lambda_2^{-1}(1-\lambda_2^{-1}\delta_1)^{-1}\cdot$$

$$[\theta(v_t+x_t) + \delta_0 + \delta_1 z_{t-1}] + \lambda_1 n_{t-1}$$

$$+ b_1\lambda_2^{-1}(1-\lambda_2^{-1}\rho)^{-1}a_t .$$

Equation (44) is a full solution for n_t in the sense that n_t is related only to variables that are observed at t(0). That is, n_t is written as a linear function of $I_{t(0)}$.

Equilibrium employment is related positively to once lagged employment, to foreign price (v_t) and terms of trade (x_t) surprises, to the prior expected value of the terms of trade, and to the shock to technology.

To solve for the equilibrium nominal wage, substitute equation (44) into equation (27) to obtain

$$(45)\quad w_t = -b_1\lambda_2^{-2}g_1^{-1}(1-\lambda_2^{-1})^{-1}\delta_0 + [1 - b_1g_1^{-1}\lambda_2^{-1}(1-\lambda_2^{-1}\delta_1)^{-1}\theta]\cdot$$

$$(v_t + x_t) + [1-b_1g_1^{-1}\lambda_2^{-1}(1-\lambda_2^{-1}\delta_1)^{-1}](\delta_0+\delta_1 z_{t-1})$$

$$- \lambda_1 g_1^{-1}n_{t-1} + [1-b_1\lambda_2^{-1}g_1^{-1}(1-\lambda_2^{-1}\rho)^{-1}]a_t$$

$$+ \bar{p}_t^* + \bar{s}$$

where $\bar{p}_t^* = E(p_t^*|I_{t-1})$.

Notice that the nominal wage moves one-for-one with the prior expected domestic price level ($\bar{p}_t^* + \bar{s}$).

Therefore a fully anticipated change in the world price level leaves the real wage unchanged. This is because such a change does not affect the perceived terms of trade, $E_{t(0)}z_t$. Notice also that v_t+x_t have an ambiguous impact on w_t. This arises because a v_t or x_t shock increases the demand for labour, thereby tending to increase w_t, and increases the supply of labour, thereby tending to reduce w_t. The overall impact of v_t and x_t shocks on n_t is of course unambiguously positive.

2.3 THE OUTPUT SOLUTION

Output is viewed as being decomposable into a natural or trend component, y_{nt} ($y_{nt} = a_0 + a_1 t$), and a cyclical component, y_{ct}:

$$(46)\quad y_t = y_{nt} + y_{ct} .$$

Write a log-linear production function as $y_{ct} = c_1 n_t$, $c_1 > 0$, which in combination with equation (44) means that

$$(47)\quad y_{ct} = c_1 b_1 \lambda_2^{-2}(1-\lambda_2^{-1})^{-1}\delta_0 + c_1 b_1 \lambda_2^{-1}(1-\lambda_2^{-1}\delta_1)^{-1} \cdot [\theta(v_t+x_t)+\delta_0+\delta_1 z_{t-1}]+c_1\lambda_1 n_{t-1}+c_1 b_1 \lambda_2^{-1}(1-\lambda_2^{-1}\rho)^{-1}a_t .$$

Now noting that $c_1 n_{t-1} = y_{t-1} - y_{nt-1}$ and using this in (47), we arrive at

$$(48) \quad y_{ct} = \beta + \gamma\theta(v_t + x_t) + \gamma(\delta_0 + \delta_1 z_{t-1}) + \lambda y_{ct-1} + \varepsilon_t ,$$

$$\varepsilon_t = \rho\, \varepsilon_{t-1} + \omega_t , \quad |\rho| < 1 ,$$

where

$$\beta = c_1 b_1 \lambda_2^{-2} (1-\lambda_2^{-1})^{-1} \delta_0$$

$$\gamma = c_1 b_1 \lambda_2^{-1} (1-\lambda_2^{-1}\delta_1)^{-1}$$

$$\lambda = \lambda_1 , \quad 0 < \lambda < 1$$

$$\varepsilon_t = c_1 b_1 \lambda_2^{-1} (1-\lambda_2^{-1}\rho)^{-1} a_t$$

$$\omega_t = c_1 b_1 \lambda_2^{-1} (1-\lambda_2^{-1}\rho)^{-1} u_t$$

and

$$E(\omega_t) = 0 , \quad E(\omega_t)^2 = c_1^2 b_1^2 \lambda_2^{-2} (1-\lambda_2^{-1}\rho)^{-2} \sigma_u^2 = \sigma_\omega^2 .$$

Equation (48) is the solution for cyclical output in this economy. It is an open economy version of the Lucas (1973) supply function and is to be compared to the extensions of the Lucas supply function to the open economy by Parkin, Bentley and Fader (1979). Equation (48) states that cyclical output in the small, open specialized economy depends positively on world price and terms of trade surprises, the impact of these surprises being greater the larger is the variance of the terms of trade, and smaller the larger is the variance of the world price level. Output also depends positively on the prior expected value of the terms of trade $(\delta_0 + \delta_1 z_{t-1})$, independently of the value of θ. Output also depends positively, with coefficient less than unity, on the lagged value of cyclical output. This arises from the non-linear costs of adjusting employment and is one of the sources of persistence in the model. Terms of trade and world price shocks act as a stimulus to output in period t but their effects persist to future values of output through the coefficient λ. A second source of persistence in the model arises from the shock to output, ε_t, which follows a first-order autoregressive process. This in turn arises from the first-order process followed by the technology shock a_t. There is yet a third source of persistence, arising from the prior expectation of the terms of trade, $\delta_0 + \delta_1 z_{t-1}$. A unit shock to the terms of trade at time t affects output at time t by the amount $\gamma\theta$ but it also affects output at time t+1 by the amount γ since it affects the time t+1 prior expectation of the terms of trade, $\delta_0 + \delta_1 z_t$.

2.4 EMPLOYMENT AND OUTPUT UNDER A FLEXIBLE EXCHANGE RATE

Solutions for employment and output have been found under the assumption that the exchange rate is fixed at $\bar{s}$. It remains to be shown that the exchange rate regime is of no consequence for the determination of employment and output.

To show this, assume the exchange rate to be variable. It may vary exogenously as a result of manipulation by the authorities or as a result of fluctuations in the currency to which it is pegged, or it may vary endogenously (which is what is usually meant by a flexible exchange rate). If it varies endogenously, it is assumed that its value is determined at the end of each period t, at t(1), and therefore is unknown at t(0). In either case we write the log-linear labour demand equation as

$$(49)\quad n_t = -g_1(w_t - E_{t(0)}p_{xt} - a_t)$$

which is to be compared to the labour demand equation for fixed exchange rate, equation (22). The only difference between equations (49) and (22) is that in (49) $E_{t(0)}p_{xt}$ replaces p_{xt} because under flexible exchange rates the exchange rate s_t, and hence the domestic currency price of output p_{xt}, are both unknown at the beginning of the period.[6] The labour supply equation under a flexible exchange rate will be the same as that under a fixed exchange rate - equation (21) still holds. Therefore equilibrium employment follows the difference equation

$$(50)\quad E_{t(0)}n_{t+1} - [k_1 + \frac{b_1}{g_1}]n_t + k_2 n_{t-1}$$

$$= -b_1 E_{t(0)}[p_{xt} - p_t + a_t]$$

which is identical to equation (28), the difference equation describing equilibrium employment under a fixed exchange rate. This means that the solutions for employment and output are unchanged from those obtained for a fixed exchange rate regime.

The reason for the irrelevance of the exchange rate regime to output determination in this model is that the exchange rate s_t affects p_{xt} and p_t equally, since $p_{xt} = p^*_{xt} + s_t$ and $p_t = p^*_t + s_t$. Thus

$$E_{t(0)}(p_{xt}-p_t) = E_{t(0)}(p^*_{xt}-p^*_t) = E_{t(0)}z_t$$

and since the exchange rate is not observed at t(0) it plays no part in the revision of the prior expectation of the terms of trade[7] z_t. Therefore the exchange rate is a purely nominal variable and is perceived as such. While s_t affects the perceived levels of p_{xt} and p_t it does not affect perceived relative prices in any way and therefore has no effect on the equilibrium levels of employment or output. Devaluations will have no effect other than to raise the nominal wage by an equal amount, thereby leaving the real wage, measured in terms of both the exported and imported good, unchanged.

The finding that employment, the real wage, and output are independent of the exchange rate does not mean that the exchange rate regime is of no importance for anything real. In fact, the exchange rate regime is of importance to the allocation of income between consumption and saving (changes in real balances). A flexible exchange rate allows for a rate of inflation different to that under a fixed rate (where it will equal foreign inflation) and thereby affects consumption and real balances. For example, the model predicts that an economy with a high rate of inflation will have higher consumption and a lower rate of savings than another economy with a lower inflation rate, all other things being equal.[8]

2.5 SUMMARY

We now have the solution for output, which is the same under the two alternative exchange rate regimes. In finding the solution for output the primary theoretical purpose of this study has been fulfilled. The model does however make predictions about the other endogenous variables and these deserve investigating. This is done in Chapter 3 where a log-linear demand for money function is adopted and, given the solution for output, the solutions for the balance of payments under fixed exchange rates and the price level and exchange rate under flexible exchange rates are calculated. Chapter 3 also provides a comparison of fixed and flexible rates with regard to the solutions for the endogenous variables.

CHAPTER 2 - FOOTNOTES

1. Notice that in equation (21), I have ignored Jensen's inequality which, in this case, states that

$$E_{t(0)}\left(\frac{w_t}{p_t}\right) \neq \frac{E_{t(0)} w_t}{E_{t(0)} p_t} .$$

2. In general it would be preferable to specify the exogenous variables as coming from general ARIMA processes such as

$$\nu_1(L) p_t^* = \nu_0 + \nu_2(L) v_t$$

$$\delta_1(L) z_t = \delta_0 + \delta_2(L) x_t$$

$$\rho(L) a_t = \mu(L) u_t$$

However, it seemed to be necessary to make specific statements about the nature of these processes in order to calculate the expectations of future values of the exogenous variables. Given the apparent necessity, rather than inventing processes, I used the ones turned up by the data analyzed in Chapter 4.

3. The solution procedure used here is borrowed from Sargent (1979). A good example of this procedure is given on pages 197-199.

4. The justification for this procedure is weak since the resort to log-linear equations means that (21)

is unrelated to the Euler equation (12). In any case, solving the unstable root forward is necessary to ensure a stable solution.

5. In addition to p_{xt}, there are of course several variables observed at $t(0)$. These include a_t and $\bar{s}$. These however convey no additional information to that provided by the observation of p_{xt}. Sargent (1979) gives several examples of the recursive projection formula.

6. That is, $p^*_{xt} + \bar{s}$ is known at $t(0)$ while $p^*_{xt} + s_t$ is not because s_t is determined at $t(1)$. Agents do observe an exchange rate at $t(0)$ but it is the exchange rate determined at the end of the last period. With s_t variable, agents therefore observe $p^*_{xt} + s_{t-1} = p^*_{xt} + s_t(0)$ at time $t(0)$.

7. When endogenous, the exchange rate is determined at the end of the period. The exchange rate observed at $t(0)$ was determined at $t-1(1)$ and has no new informational content. Suppose though that the exchange rate varied exogenously and was set by the authorities at $t(0)$. In this case s_t is observed at $t(0)$. However, it has no informational content relevant to calculating the expectation of the terms

of trade and still has no effect on employment, the real wage or output.

8. These results were established in Chapter 1 and are summarized in equations (15) and (16).

CHAPTER 3

THE BALANCE OF PAYMENTS, PRICE LEVEL AND EXCHANGE RATE SOLUTIONS

3.1 INTRODUCTION

In Chapter 2, the solutions for output under both fixed and flexible exchange rate regimes were found. Output was shown to be independent of the exchange rate regime.

Given the output solution, it is now possible to solve for the balance of payments under a fixed exchange rate and the price level and exchange rate under a flexible exchange rate. In section 3.2 of this chapter, the solution for the balance of payments under a fixed exchange rate is obtained. Section 3.3 provides the solutions for the domestic price level and the exchange rate under flexible rates. In the process, a log-linear version of our original money demand function, equation (15) of Chapter 1, is specified.

The equations common to both regimes are:

$$(51) \quad \mathring{y}_{ct} = \beta + \gamma\theta(v_t + x_t) + \gamma(\delta_0 + \delta_1 z_{t-1}) + \lambda y_{ct-1} + \varepsilon_t$$

$$\varepsilon_t = \rho\, \varepsilon_{t-1} + \omega_t$$

(52) $y_t = y_{nt} + y_{ct}$

(53) $m_t = p_t + a(y_t+z_t) - bE_t(p_{t+1}-p_t)$, $a,b > 0$

(54) $p_t = p_t^* + s_t$

(55) $\Delta p_t^* = \nu_0 + \nu_1 \Delta p_{t-1}^* + v_t$

(56) $z_t = \delta_0 + \delta_1 z_{t-1} + x_t$

where m_t is nominal money and (y_t+z_t) is real income ($\log Q_t$).

Equations (51), (52), (54), (55), and (56) are familiar from the last chapter. Equation (53) is new however. It is the money demand function and is a log-linear version of the original money demand function, equation (15). This log-linearization is in accordance with the log-linearization of the model that was carried out in Chapter 2.

Solution of the above model for the balance of payments, the price level and the exchange rate is much simplified by the fact that the model is recursive. Under both regimes, output is determined in equations (51) and (52). Under a fixed exchange rate system, the domestic price level is determined by (54) and then, the endogenous money supply is determined by equation (53). Under a flexible exchange rate system, the price level is determined by (53), since m_t is now exogenous, and the exchange rate by (54).

In section 3.4, the fixed and flexible rates solutions for output, the balance of payments, the price level and the exchange rate are compared. Section 3.5 is a summary.

3.2 FIXED EXCHANGE RATES

The fixed exchange rate regime considered here is quite general and is perhaps better termed an exogenous exchange rate regime. It corresponds to what Weber (1981) calls an exchange rate rule. Two special cases can be discerned: 1) where the currency of the small country is pegged to that of another country and fluctuates against all others to the extent that the currency to which it is pegged fluctuates, and 2) where the effective exchange rate is fixed.

The exogeneity of the exchange rate means that the money stock is an endogenous variable and monetary adjustment takes place through the balance of payments. The money supply is fully backed by foreign assets and domestic credit:

(57) $m_t = \log(F_t + D_t)$.

Noting that $E_t p^*_{t+1} = \nu_0 + (1+\nu_1)p^*_t - \nu_1 p^*_{t-1}$, substitution of this into equation (53) and equating money demand and supply yields

(58) $$\log(F_t+D_t) = p_t + a(y_t+z_t) - b\nu_1(p^*_t-p^*_{t-1}) - bE_t(s_{t+1}-s_t) .$$

Taking the first-difference of this last equation, we can write

(59) $$\Delta f_t = \alpha^{-1}[\Delta p_t + a\Delta(y_t+z_t) - b\nu_1\Delta(p^*_t-p^*_{t-1}) - b\Delta E_t(s_{t+1}-s_t)] - (1-\alpha)\alpha^{-1}\Delta d_t ,$$
$$0 < \alpha < 1 ,$$

where f_t is the logarithm of foreign reserves, d_t is the logarithm of domestic credit, and $\alpha = F_t/(F_t+D_t)$.

Equation (59) is in the form of the reserve flow equation of the monetary approach to the balance of payments (see for example Frenkel and Johnson (1976)). It relates the rate of change of foreign reserves positively to the rate of change of the demand for money and negatively to the rate of change of domestic credit. As is emphasized by Mussa (1976) this is by no means just a monetary (in the strict sense of the word) theory of the balance of payments. Real shocks such as terms of trade and supply shocks affect the balance of payments through their effects on income.

Substitution of equations (51) and (52) into equation (59) gives the coefficient of x_t on Δf_t as:

$$\alpha^{-1}a(\gamma\theta + 1) > 0 .$$

Terms of trade (x_t) shocks have an unambiguous positive impact on the balance of payments since an x_t shock directly increases the valuation of output and also increases output itself through $\gamma\theta$, both of which increase the demand for money through a.

Foreign nominal shocks however have an ambiguous impact on the balance of payments since the coefficient of v_t on Δf_t is

$$\alpha^{-1}[1 + a\gamma\theta - b\nu_1] \gtrless 0 .$$

There are three separate effects at work here. First, a v_t shock increases p_t^* and hence p_t and therefore increases the demand for money. Secondly, a v_t shock increases output through $\gamma\theta$ and hence the demand for money through a. Both these effects are positive. The third effect though of a v_t shock is to generate expectations of inflation which tends to reduce the demand for money.[1]

Domestic credit has a negative effect on the balance of payments and the domestic authorities can control the balance of payments by controlling domestic credit. The lagged value of the terms of trade has a positive impact on Δf_t in a way analogous to that in which x_t effects Δf_t. Supply shocks have a positive effect on Δf_t through their effects on output.

Finally, it is interesting to compute the effect on f_t of an announced change in the exchange rate, say a pre-announced devaluation. An announced (at time t) and believed devaluation at time t+1 has a negative impact on current foreign reserves through $-b\alpha^{-1} < 0$. This follows because an expected devaluation reduces the demand for money today and thereby induces a reserve loss today.

3.3 FLEXIBLE EXCHANGE RATES

Under flexible exchange rates, the money supply is exogenous. The price level is determined by money market equilibrium and the exchange rate fluctuates to maintain a zero balance of payments. This section derives and interprets the solutions for the domestic price level p_t and the exchange rate s_t.

Equating money supply to money demand in equation (53) and rearranging gives us a first-order difference equation in p_t:

$$(60) \quad [1 - \frac{(1+b)}{b}B]E_{t-1}p_t = -\frac{1}{b}(m_{t-1} - ay_{t-1} - az_{t-1}) \quad .$$

where the operator B is such that $B^i[E_t X_t] = E_t X_{t-i}$. Since $(1+b)/b > 1$ we take the forward solution to ensure boundedness of the solution. Then update the information set to get:

$$(61) \quad p_t = \frac{1}{1+b} \sum_{i=0}^{\infty} (\frac{b}{1+b})^i E_t(m_{t+i} - ay_{t+i} - az_{t+i}) \quad .$$

This last equation states that the current price level depends on present and all expected future values of all the variables determining the demand for and supply of money. This is a standard result in the literature. Examples in the open economy literature are to be found in Bilson (1978) and in the appendix to Mussa (1976). A good reference in the closed economy literature is Sargent and Wallace (1973). Such results arise when there is an expectation of the future value of an endogenous variable in the demand for money equation.

To simplify matters and to obtain a solution in terms of I_t, I assume that the money supply follows a random walk. This is for illustrative purposes only and the actual process followed by m_t is an empirical issue. The m_t process assumed is

$$(62) \quad m_t = m_{t-1} + n_t$$

where n_t is normally distributed with zero mean, and is distributed independently of all other exogenous shocks to the system. The solution for p_t may be conjectured to have the form

$$(63) \quad p_t = \phi_0 + \phi_1 m_t + \phi_2 v_t + \phi_3 x_t + \phi_4 z_{t-1} + \phi_5 \varepsilon_t + \phi_6 y_{ct-1} + \sum_{i=0}^{\infty} \phi_{7i} y_{nt+i}$$

where the ϕ_i, i = 1,2,3,4,5,6,7 are constants.[2] To find the ϕ_i's, lead (63) once and take the expectation based on I_t to give

$$(64) \quad E_t p_{t+1} = \phi_0 + \phi_1 m_t + \phi_4 z_t + \phi_5 \rho \varepsilon_t + \phi_6 \beta + \phi_6 \gamma\theta v_t + \phi_6 \gamma\theta x_t + \phi_6 \gamma \delta_0 + \phi_6 \gamma \delta_1 z_{t-1} + \phi_6 \lambda y_{ct-1} + \phi_6 \varepsilon_t + \sum_{i=0}^{\infty} \phi_{7i} y_{nt+i+1} .$$

Substitution of equation (64) into equation (53) and equating terms with the postulated solution (equation (63)) yields

$$\phi_1 = (1+b)^{-1}(1+b\phi_1)$$

$$\phi_2 = (1+b)^{-1}(b\phi_6\gamma\theta-a\gamma\theta)$$

$$\phi_3 = (1+b)^{-1}(b\phi_4+b\phi_6\gamma\theta-a\gamma\theta)$$

$$\phi_4 = (1+b)^{-1}(b\phi_4\delta_1+b\phi_6\gamma\theta_1-a\gamma\theta_1)$$

$$\phi_5 = (1+b)^{-1}(b\phi_5\rho+b\phi_6-a)$$

$$\phi_6 = (1+b)^{-1}(b\phi_6\lambda-a\lambda)$$

$$\phi_7 = -a(1+b)^{-1}\left(\frac{b}{1+b}\right)^i \qquad i = 0,1,2,\ldots$$

The solutions for ϕ_i, $i = 1,2,3,4,5,6$ resulting from the above system of equations are

$$\phi_1 = 1$$

$$\phi_2 = \frac{-a\gamma\theta}{B_1}$$

$$\phi_3 = \frac{-[a\gamma\delta_1 b(1-\theta)-a\gamma\theta(1+b)]}{B_1 \cdot B_2}$$

$$\phi_4 = \frac{-a\gamma\delta_1(1+b)}{B_1 \cdot B_2}$$

$$\phi_5 = \frac{-a(1+b)}{B_1 \cdot B_3}$$

$$\phi_6 = \frac{-a\lambda}{B_1}$$

where

$B_1 = 1+b(1-\lambda)$

$B_2 = 1+b(1-\delta_1)$

$B_3 = 1+b(1-\rho)$

The full solution for p_t is therefore

$$(65)\quad p_t = \phi_0 + m_t - \frac{a\gamma\theta}{B_1} v_t - \frac{[a\gamma\delta_1 b(1-\theta)+a\gamma\theta(1+b)]}{B_1 \cdot B_2} x_t - \frac{a\gamma\delta_1(1+b)}{B_1 \cdot B_2} z_{t-1} - \frac{a(1+b)}{B_1 \cdot B_3} \varepsilon_t - \frac{a\lambda}{B_1} y_{ct-1} - \frac{a}{1+b} \sum_{i=0}^{\infty} \left(\frac{b}{1+b}\right)^i y_{nt+i} .$$

The exchange rate solution is found by using the fact that $s_t = p_t - p_t^*$:

$$(66)\quad s_t = \phi_0 + m_t - [1 + \frac{a\gamma\theta}{B_1}]v_t - \frac{[a\gamma\delta_1 b(1-\theta)+a\gamma\theta(1+b)]}{B_1 \cdot B_2} x_t - \frac{a\gamma\delta_1(1+b)}{B_1 \cdot B_2} z_{t-1} - \frac{a(1+b)}{B_1 \cdot B_3} \varepsilon_t - \frac{a\lambda}{B_1} y_{ct-1} - \frac{a}{1+b} \sum_{i=0}^{\infty} \left(\frac{b}{1+b}\right)^i y_{nt+i} - \nu_0 - p_{t-1}^* - \nu_1(p_{t-1}^* - p_{t-2}^*) .$$

The solutions for p_t and s_t show that the money supply has a one-for-one impact on both. This is a reflection of the fact that domestic monetary variables have no impact on output in this model.

Terms of trade shocks have an unambiguously negative effect on p_t and s_t. An x_t shock has a positive impact on output and a direct impact on income. It also increases z_t and hence z_{t+1} which has the effect of reducing $E_t p_{t+1}$. All of these effects work positively on the demand for money and thereby have a negative effect on p_t and s_t as well.

A foreign nominal shock has a negative impact on p_t and s_t. The effect on p_t works solely through the effect of a v_t shock on y_{ct}. An interesting feature though is that the exchange rate "overshoots" in response to a v_t shock. That is, a positive v_t shock causes the exchange rate to appreciate by more than the size of the v_t shock. In a world of complete certainty, the exchange rate would move one-for-one (in the opposite direction) with foreign price movements. However, with incomplete current information, a v_t shock has a positive effect on output, increasing the demand for money and causing s_t to fall by more than the full amount of the v_t shock.

The lagged value of the terms of trade effects p_t and s_t negatively, as does x_t. Supply shocks also have a negative effect on p_t and s_t, as do y_{ct-1} and current and all future values of the natural rate of output, y_{nt}.

3.4 A COMPARISON OF FIXED AND FLEXIBLE EXCHANGE RATE REGIMES

While it is true that many small economies are on fixed or pegged exchange rate systems, a comparison of such a system with a flexible exchange rate system is of interest, especially given the continuing debate over the relative desirabilities of the two regimes. The traditional conclusion is that a flexible exchange rate regime allows independence in domestic price determination and insulates the domestic economy from foreign disturbances, particularly nominal disturbances. An even stronger claim has been that a flexible rate allows the domestic authorities to stabilize output by choosing a point on the Phillips curve.[3]

However, in the model under study here, it has been shown that output is identical under both regimes and, therefore, that a flexible exchange rate does not provide insulation of the domestic economy from foreign nominal and real disturbances, despite zero capital mobility. Similar conclusions have been reached by Burton (1980), Cox (1980) and Saidi (1980). Furthermore, output in both regimes is independent of domestic monetary variables. Money is neutral in the strong sense that even unanticipated domestic monetary shocks have no output effect.

In the discussion that follows the differences in the impact of the exogenous variables x_t, v_t, n_t and ε_t on output, the price level, the exchange rate and foreign reserves will be highlighted, though the discussion with respect to output is trivial.

Terms of Trade Shocks

TABLE 2: COEFFICIENT ON x_t

	FIXED	FLEXIBLE
y_t	$\gamma\theta \geq 0$	$\gamma\theta \geq 0$
p_t	0	$\frac{-[a\gamma\delta_1 b(1-\theta)+a\gamma\theta(1+b)]}{B_1 \cdot B_2} < 0$
s_t	0	$\frac{-[a\gamma\delta_1 b(1-\theta)+a\gamma\theta(1+b)]}{B_1 \cdot B_2} < 0$
f^t	$\alpha^{-1}a(\gamma\theta+1) > 0$	

Under a fixed exchange rate regime terms of trade shocks have no effect on the domestic price level and have a positive effect on reserve flow. In the case of a flexible rate, positive x_t shocks reduce the price level and cause the exchange rate to appreciate. In a world with highly volatile terms of trade (large σ_x^2), the more will the price level and the exchange rate fluctuate under flexible rates, and the balance of payments under a fixed rate. In both regimes of course, output would be highly variable as well. Therefore, with high real variance, a flexible rate system provides no insulation for output, the price level or the exchange rate. In fact, even with low σ_x^2 $(\theta \to 0)$, there is still no insulation. It should be noted that z_{t-1} affects y_t, p_t, s_t and f_t in a similar fashion to x_t.

Foreign Price Shocks

TABLE 3: COEFFICIENT ON v_t

	FIXED	FLEXIBLE
y_t	$\gamma\theta \geq 0$	$\gamma\theta \geq 0$
p_t	1	$-\frac{a\gamma\theta}{B_1} \leq 0$
s_t	0	$-[1 + \frac{a\gamma\theta}{B_1}] \leq -1$
f_t	$\alpha^{-1}(1+a\gamma\theta-\nu_1 b) \gtrless 0$	0

As Table 3 shows, a positive foreign price level shock increases the domestic price level by the full amount of the shock and can have a positive or negative effect on the balance of payments under a fixed rate. Under a flexible rate it would reduce the domestic price level and appreciate the currency by an amount greater (in absolute terms) than the size of the foreign price level shock. Thus the fixed-flexible rate tradeoff involves substitution of balance of payments and price variability under fixed rates for price and exchange rate variability under flexible rates, in response to world nominal disturbances.

Consider however the case of highly volatile world prices (σ_v^2 large relative to σ_x^2). Then $\theta \rightarrow 0$ and the output effect of a v_t shock disappears. Now v_t shocks have no effect on the price level under a flexible rate and the exchange rate moves in tandem, in the opposite direction, with the world price level. In this case, a flexible exchange rate can truly be said to provide insulation of the domestic economy from foreign nominal disturbances (though it is still subject to the effects of real shocks). On the other hand, even with $\theta=0$, the balance of payments and the price level under a fixed rate will react to v_t shocks. Indeed, the variance of domestic prices will equal the variance of world prices and it is now more likely that foreign inflation will worsen the balance of payments by generating expectations of further inflation and reducing the demand for money.

Clearly then, a world with volatile foreign prices favours the adoption of a flexible rate, though this will only produce lower domestic price variability than a fixed rate system if domestic monetary variance is low. This result gives some support for the traditional view that a flexible rate is better when foreign nominal shocks predominate. (See Artus and Young (1979).)[4]

Domestic Monetary Shocks

TABLE 4: COEFFICIENT ON n_t

	FIXED	FLEXIBLE
y_t	0	0
p_t	0	1
s_t	0	1
f_t	$-\alpha^{-1}(1-\alpha) < 0$	0

Under a fixed exchange rate domestic monetary shock is to be interpreted as the current disturbance to the domestic credit process. Thus $n_t = d_t - E_{t-1}d_t$. One effect of a flexible exchange rate is that the small economy has a degree of independence in domestic price determination while there is no scope for this under a fixed rate. Monetary instability will show up in both regimes. Under a fixed rate it shows up in the balance of payments while under a flexible rate it does so in the price level and exchange rate.

Table 4 shows the now familiar result that under a fixed exchange rate, output and the domestic price level are determined independently of domestic monetary conditions. For instance, Weber (1981) finds that output under fixed rates is independent of money demand. Boyer (1978) finds that a fixed exchange rate is optimal when shocks occur only in the money market and that is the market in which the authorities are intervening. The results here go further, however, in showing that in the type of economy modelled here, output is determined independently of domestic monetary conditions under flexible rates as well.

Domestic Supply Disturbances

TABLE 5: COEFFICIENT ON ε_t

	FIXED	FLEXIBLE
y_t	1	1
p_t	0	$\frac{-a(1+b)}{B_1 \cdot B_3} < 0$
s_t	0	$\frac{-a(1+b)}{B_1 \cdot B_3} < 0$
f_t	$\alpha^{-1}a > 0$	0

The domestic supply shock is really a technology shock since ε_t is linearly related to a_t. Under a fixed rate supply disturbances have a positive effect on reserves and no effect on the domestic price level while under a flexible rate they induce a fall in the price level and the exchange rate. The size of the impact of ε_t on p_t and s_t under flexible rates depends positively on λ and ρ, both of which cause the effects of an ε_t disturbance to persist into the future, thereby reducing expected inflation.

3.5 SUMMARY

The model analyzed in this thesis makes predictions about the behaviour of output over the business cycle in small, open, specialized economies. Given the predicted behaviour of output, the model also makes predictions about the behaviour of the balance of payments under fixed exchange rates, and the price level and exchange rate under flexible exchange rates. These solutions found for these variables are quite standard monetarist or classical in form. Any major differences arise because income determination is different.

The fact that foreign nominal and real shocks affect the balance of payments under fixed rates and the price level under flexible rates arises from the fact that these foreign variables have an impact on output, under both regimes. Indeed, an interesting feature of this model is that in general, a flexible exchange rate does not insulate the domestic economy from foreign nominal and real disturbances. The degree of insulation provided by flexible rates diminishes as real (terms of trade) variance increases. The situation reverses however when foreign nominal variance is relatively high. Then a flexible exchange rate, in accordance with the traditional conclusion, insulates domestic output and prices from foreign nominal shocks. Of course this model allows no room for domestic monetary stabilization of output under either regime.

These predictions rest, for the most part, on the "correctness" of the output equation. It is necessary then to test the predictions that the model makes about output. This is done in Chapter 4.

CHAPTER 3 - FOOTNOTES

1. This last effect is dependent upon the AR(1,1) process for the world price level. In general, this effect should hold whenever the foreign price level process is "sluggish" and a change in the world price level today is expected to persist into the future.

2. Here, as in equation (61), the constant in the complementary function is set to zero to ensure boundedness of the solution.

3. For a good survey of these issues, see Artus and Young (1979).

4. This result is derived under conditions of zero capital mobility. Flood (1979) finds that this does not hold true under conditions of capital mobility because foreign interest rates come into play. My conjecture is that allowing for capital mobility would leave my solution for output unchanged, but would change the balance of payments, price level and exchange rate solutions. Flood and Marion (1982) used a model similar to that of Flood (1979), but with wage indexing. They find that with full indexing, a fixed exchange rate provides full insulation from foreign disturbances. A flexible rate does not

provide insulation. Capital mobility complicates things because not only foreign prices but also foreign interest rates affect the domestic economy.

CHAPTER 4

EMPIRICAL RESULTS

4.1 INTRODUCTION

This chapter tests the predictions of the model developed in Chapters 1 and 2 for the behaviour of output. Empirical testing of the predictions for output in Lucas (1973) and Parkin, Bentley and Fader (1981) was a two-stage process - first the time-series predictions were tested, then the cross-country predictions. In the case of the model under study here, however, the time-series and cross-country tests can be combined. This is so because a direct estimate of θ, the coefficient predicted to vary systematically across countries, is obtained in this case. The cross-country test is simply another restriction that is imposed when the output equation is estimated using the time-series data. The restrictions are then tested against an unrestricted model. These tests are performed using annual data for thirteen countries in the Caribbean, Central America, Africa and South-East Asia.

The first step in the testing of the model is identification and estimation of the exogenous processes for the world price level, p_t^*, and the terms of trade, z_t, for each country. The world price level process is assumed to be common to all countries. From these estimated processes, the series for the world price level shock, v_t, the terms of trade shock, x_t, for each country, and the expected terms of trade $E_{t-1}z_t$ for each country are obtained. In addition, estimates of the variance of the world price level shock, σ_v^2, and the variance of the terms of trade shock, σ_x^2, for each country are calculated. These provide an estimate of $\theta = \sigma_x^2/(\sigma_v^2+\sigma_x^2)$ for each country.

The second step is to calculate the series for detrended output, y_{ct}, for each country, and then to use θ and the calculated series for v_t, and for x_t and $E_{t-1}z_t$ for each country in estimating the output equation:

$$(67) \quad y_{ct} = \beta + \gamma[\theta(v_t + x_t) + \bar{z}_t] + \lambda y_{ct-1} + \varepsilon_t ,$$

$$\varepsilon_t = \rho\, \varepsilon_{t-1} + \omega_t , \quad |\rho| < 1,$$

where $\bar{z}_t = E_{t-1}z_t$.

Equation (67) is the fully restricted form of the output equation. It contains all the restrictions implied by the model and is tested by means of a likelihood ratio test. In an effort to compare the model to other contending economic models, the model is also tested against two alternative hypotheses: namely a simple fixed wage Keynesian model and a full information classical model.

This chapter proceeds as follows: Section 4.2 is a short note on the countries and the data; section 4.3 deals with the identification and estimation of the exogenous processes; section 4.4 presents the estimated output equation; section 4.5 tests some alternative hypotheses and section 4.6 is a summary. Appendix A gives the estimates of some alternative output equations and Appendix B deals with the data and provides time-series plots.

4.2 THE COUNTRIES AND THE DATA

The countries selected for estimating and testing the model all have the common feature that they are highly specialized in the production of a few goods. The variable used to identify the degree of openness and specialization is the ratio of exports to GDP.[1] Table 6 lists the countries, their exports/GDP ratios and their main products. All of the countries were on pegged exchange rate systems for the sample period, though for some there have been significant changes in the level of the peg from time to time (see the International Financial Statistics Supplement on Exchange Rates (1981)).

The output equation is estimated using annual data from various issues of International Financial Statistics (IFS), as well as a database from the Supplement on Trade Statistics (1982). The series for each country lie

TABLE 6: THE DEGREE OF OPENNESS

Country	Exports/GDP (%)	Major Exports
Costa Rica	25.2	Coffee, bananas, sugar, beef.
Dominican Republic	24.8	Sugar, ferronickel, coffee, tobacco, cacao, bauxite.
Fiji	25.3	Sugar.
The Gambia	48.8	Groundnut products.
Guyana	72.2	Sugar, bauxite, alumina, rice.
Honduras	27.4	Bananas, coffee, wood, frozen beef.
Jamaica	26.4	Alumina, bauxite, sugar.
Kenya	20.0	Petroleum, coffee, tea.
Malaysia	41.3	Rubber, palm oil, tin, timber, petroleum.
Mauritius	48.7	Sugar.
Nicaragua	23.7	Cotton, coffee, meat.
Trinidad & Tobago	68.0	Petroleum.
Zambia	32.9	Copper.

Source: International Financial Statistics, various issues.

within the period 1952-1981, though for most countries the series fall well within this period. The sample sizes vary considerably, from 15 years for Costa Rica to 27 years for Trinidad and Tobago. Estimation of the supply equation requires time series on the world price level. In addition, the terms of trade and output are required for each country. A detailed description of how the data were obtained is given in Appendix B. All data were converted to logarithmic terms before estimation.

4.3 THE EXOGENOUS PROCESSES

First, it is necessary to identify the processes for the exogenous variables p_t^* and z_t. The objective was to obtain a parsimonious and adequate representation of the data. Thus, following Box and Jenkins (1970), an effort was made to employ the smallest number of parameters that give an adequate representation of the data. The identification procedure involves estimation of the correlogram and partial autocorrelation functions of the raw and differenced data and examining these with a view towards identifying an ARIMA process.[2]

After identification of the processes, they were estimated by a maximum likelihood Box-Jenkins procedure.[3] After estimation came diagnostic checking to verify the adequacy of the model as a description of the data. Plots of the residuals were examined for any distinct divergences from randomness. The sample autocorrelations of the residuals were examined and compared to standard errors computed from Bartlett's formula.[4] Since this method of checking for randomness can underestimate the discrepancies, I also used the Box-Pierce Q statistic.[5] This offers a test on the smallness of a whole set of sample autocorrelations. The Q statistic was compared to the critical levels for 12 and 24 lags. The normalized cumulative periodogram was also examined as a further test of positive or negative serial correlation amongst the residuals. In addition, the cross-correlations between the residuals, current and future, and the current expected value of the variables were examined. In all cases, these were close to zero.

Table 7 presents the estimated world price level process. The world price level was found to be adequately described by a first-order autoregression in the first differences. This was suspected after it was found that, for the differenced data, only the first partial autocorrelation was significant while the autocorrelations declined gradually. Both Q(12) and Q(24) are small relative to critical values 18.3 and 33.9 respectively at the 5% significance level. The whitened residuals were used as the series for v_t, the world price level surprise. See Appendix B for plots of Δp_t^* and v_t.

TABLE 7: THE WORLD PRICE LEVEL PROCESS

$$\Delta P^*_t = \underset{(.007)}{.006} + \underset{(.082)^*}{.920} \; \Delta P^*_{t-1} + v_t$$

$R^2 = .77$, $Q(12) = 6.9$, $Q(24) = 14.1$, $T = 31$

$\sigma^2_v = .374 \times 10^{-3}$

NOTE: Figures in parentheses are standard errors. An asterisk next to a standard error indicates that the estimate is significantly different from zero at the 5% level. R^2 is the coefficient of determination. Q(12) and Q(24) are the Box-Pierce statistics for the smallness of 12 and 24 autocorrelations respectively. The Q statistic is approximately distributed χ^2 with K-q degrees of freedom where K is the number of lags and q is the order of the autoregressive process. The critical value for Q(12) is 18.3 and for Q(24), it is 33.9, both at the 5% significance level. T is the sample size.

For 12 of the 13 countries studied, the terms of trade were found to be adequately and parsimoniously described by a first-order autoregressive process. In all of these cases it was noticed at the identification stage that only the first partial autocorrelation was significantly greater than zero while the autocorrelations declined gradually. This is evidence of a first-order autoregressive process. In the case of Kenya, I could not reject the hypothesis that the terms of trade follows a random walk, especially after estimation turned up an autoregressive coefficient close to unity. The autocorrelations of the first-differenced series for Kenya were all not significantly different from zero at the 5% level of significance.

Table 8 presents the estimated AR(1) processes for the 12 countries. In all cases, the adequacy of the model is indicated by the significance of the autoregressive coefficient. Furthermore, the Q statistics indicate that the null hypothesis that the residuals are white noise cannot be rejected at the 5% level of significance.[6] Notice that in many cases the R^2 statistic is low, indicating that these are noisy time series. The plots in the Data Appendix help to bring out this fact. The residuals from the estimated equations were used as the x_t series for each country. The predicted component,

TABLE 8: THE TERMS OF TRADE PROCESSES

Country	Constant	Autoregressive Coefficient	R^2	Q(12)	Q(24)	T	σ_x^2	θ
Costa Rica	2.040 (1.108)	.572 (.226)*	.25	5.3		17	.0195	.980
Dominican Republic	2.292 (.799)*	.450 (.192)*	.20	6.8		22	.0195	.980
Fiji	1.090 (.638)	.741 (.152)*	.50	9.1		21	.0177	.978
The Gambia	1.409 (.664)*	.690 (.144)*	.38	14.8	17.7	28	.0423	.991
Guyana	.839 (.446)	.798 (.108)*	.62	9.8	12.7	31	.0180	.978
Honduras	1.828 (.962)	.630 (.193)*	.34	10.5		21	.0156	.975
Jamaica	1.230 (.628)	.714 (.145)*	.44	7.6	9.7	28	.0162	.976
Malaysia	.018 (.747)*	.638 (.151)*	.30	9.9	15.9	27	.0138	.972
Mauritius	1.730 (.817)*	.583 (.196)*	.33	8.2		20	.0223	.982
Nicaragua	1.242 (.787)	.750 (.157)*	.35	3.7		23	.0106	.964
Trinidad & Tobago	.161 (.117)	.962 (.026)*	.86	6.4	9.7	32	.0409	.990
Zambia	1.530 (.804)	.674 (.170)*	.42	5.0		23	.0474	.992

TABLE 8 (cont'd)

NOTE: Q(24) is not calculated when the sample size is less than 25. The estimate of θ for each country was calculated as $\sigma_x^2/(\sigma_v^2+\sigma_x^2)$. An estimated process was not given for Kenya because its terms of trade was modelled as a random walk. For Kenya, $\sigma_x^2 = .009$ and $\theta = .958$. See the note to Table 7 for more details.

$\hat{\delta}_0 + \hat{\delta}_1 z_{t-1}$, was used as the expected terms of trade for each country. Recall that the AR(1,1) and AR(1) processes that we have found for p_t^* and $\dot{z}_t$ respectively were in fact the ones used in earlier chapters.

Table 8 also presents the calculated θ for each of the 13 countries.[7] The estimate of θ is calculated as $\sigma_x^2/(\sigma_v^2+\sigma_x^2)$ as predicted by the model. Notice that θ is very close to unity in all cases and, indeed, varies between .958 for Kenya and .992 for Zambia. This is a very small range and reflects the fact that σ_x^2 is always much bigger than σ_v^2. The estimated σ_v^2 is .000374 while the estimated σ_x^2 ranges from .009 for Kenya to .474 for Zambia.

This predominance of relative price variance over general price variance means that the model predicts that agents in the small economy will believe that over 95% of any change in the export price level is a change in the terms of trade. Purely nominal changes will be perceived as real changes in relative prices.

4.4 THE OUTPUT EQUATION

The natural rate of output was estimated as a linear trend[8] with the residuals forming the series for cyclical output, y_{ct}:

(68) $y_t = a_0 + a_1 t + y_{ct}$.

The fully restricted supply equation, (67), was estimated for each of the 13 countries in the sample. Preliminary estimation by ordinary least squares turned up serial correlation amongst the residuals in many cases. This serial correlation is consistent with the assumption, made in Chapter 2, that the technology variable a_t follows an AR(1) process. The presence of a lagged dependent variable in the output equation means that the OLS estimator, with serially correlated residuals, is biased and inconsistent. Therefore a maximum-likelihood iterative procedure with a correction for first-order serial correlation was used to estimate the output equation.

The results of estimating equation (67) are presented in Table 9. The low R^2 in many cases indicates the importance of the variance of the productivity shock in contributing to the variance of cyclical output. The variance of the productivity shock is especially important in the cases of Kenya, Guyana, Nicaragua,/Costa Rica and The Gambia, all of which have an R^2 less than .30. The residuals ω_t were checked for whiteness by examining their autocorrelation and partial autocorrelation functions. Furthermore, the Box-Pierce Q-statistic was calculated and presented in Table 9. The null hypothesis that the

TABLE 9: THE OUTPUT EQUATION

Country	β	γ	λ	ρ	R^2	L	D.W.	Q	T
Costa Rica	-.339 (.215)	.070 (.045)	.652 (.402)	.222 (.220)*	.22	39.24	1.50	4.69	15
Dominican Republic	-1.435 (.887)	.342 (.212)	.505 (.217)*	.036 (.236)	.53	17.32	2.00	6.59	20
Fiji	-1.141 (.371)*	.272 (.088)*	.342 (.181)	.218 (.242)	.63	31.78	1.88	[illegible].32	19
The Gambia	-.479 (.416)	.106 (.093)	.478 (.214)*	-.272 (.227)	.25	17.07	1.99	7.54	20
Guyana	[illegible].510 (.337)	.123 (.082)	.113 (.235)	.077 (.244)	.17	26.24	1.82	12.73	20
Honduras	-.355 (.264)	.072 (.053)	.997 (.161)*	-.053 (.243)	.68	44.12	1.96	13.18	20
Jamaica	-.102 (.433)	.019 (.102)	.992 (.211)*	.575 (.231)*	.55	31.05	[illegible].85	6.48	21
Kenya	-.313 (.278)	.063 (.057)	-.257 (.257)	.640 (.217)*	.11	38.36	1.67	5.19	16
Malaysia	-2.223 (.319)*	.453 (.065)*	.101 (.115)	.691 (.157)*	.68	48.43	1.75	10.70	26
Mauritius	-.864 (.229)*	.207 (.055)*	.620 (.132)*	-.622 (.250)*	.88	25.40	2.29	4.48	15
Nicaragua	-.871 (.494)	.173 (.099)	.555 (.321)	.511 (.258)*	.21	37.39	1.39	6.43	20
Trinidad & Tobago	-.557 (.146)*	.143 (.036)*	.486 (.144)*	.868 (.095)*	.51	50.28	1.89	4.62	27
Zambia	-.752 (.305)*	.159 (.065)*	.726 (.120)*	-.128 (.251)	.81	25.87	1.78	5.24	22

TABLE 9 (cont'd)

NOTE: Figures in parentheses are standard errors. If a standard error is accompanied by an asterisk, then the estimate is significant at the 5% level. ρ is the autoregressive coefficient. R^2 is the coefficient of determination. L is the logarithm of the maximized value of the likelihood function. D.W. is the Durbin-Watson statistic. Given the presence of a lagged dependent variable, Durbin's h-statistic would be preferable but it was impossible to calculate this in most cases. Instead, the Box-Pierce Q-statistic was calculated and the whiteness of the residuals tested. The Q-statistic given above is for T-1 lags for each country, up to a maximum of 20 lags. The tabulated Q(14) = 23.7 and Q(20) = 31.4. Clearly, the null hypothesis of white noise residuals can not be rejected in any case.

residuals are white noise up to T-1 lags (to a maximum of 20) could not be rejected at the 5% significance level in any case.

The model predicts that γ will be positive. Table 9 shows that the estimate of γ is always positive as predicted. The estimate of γ is only significant at the 5% level in 5 cases though: Fiji, Malaysia, Mauritius, Trinidad and Tobago, and Zambia. The estimated γ varies from .019 for Jamaica to .453 for Malaysia. This variation across countries is to be expected. Reference to Chapters 1 and 2 will show that $\gamma = b_1\lambda_2^{-1}(1-\lambda_2^{-1}\delta_1)^{-1}$, and therefore γ is a function of d, u_3, h and f_1 - all parameters of preferences and technology. The theory makes no presumption that these will be constant across countries.

The model predicts that $0 \leq \lambda < 1$. The estimate of λ is positive and less than unity in 12 out of the 13 cases. In 7 of these it is significantly positive. In one case, Kenya, the estimate of λ is negative but not significantly so. The autoregressive coefficient ρ is significantly different from zero in 7 cases.

Overall, the best fits in terms of the significance of the coefficients are obtained for Mauritius, Trinidad and Tobago, Zambia, Fiji and Malaysia. The countries with a weak fit by this criterion are Costa Rica, Guyana, Kenya and Nicaragua.

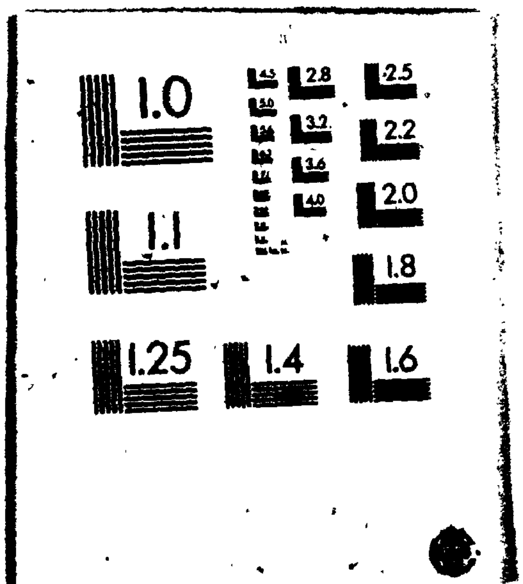
An interesting aspect of these results is the importance of real variance. In section 4.3 it was found that terms of trade variance predominates over general world price level variance so that θ is close to unity. In this section, it has been found that the variance of the (real) productivity shock is a major contributor to the variance of cyclical output. These results can be related to the prediction from Chapter 3 that a flexible exchange rate insulates the domestic economy from foreign shocks when foreign nominal variance dominates real variance. The importance of real variance in practice means that this condition is not fulfilled and a flexible exchange rate would not provide insulation of the specialized economy from foreign shocks.

4.5 SOME ALTERNATIVE HYPOTHESES

The equation estimated in the last section embodied all the restrictions of the model in terms of the relationship between the coefficients. It is appropriate now to test those restrictions.

In testing the restrictions implicit in the supply equation, (67), the procedure of estimating an unrestricted supply equation and then testing the overidentifying restrictions by means of a likelihood ratio test is adopted.

2 OF/DE 2



The specific procedure used was suggested by Hoffman and Schmidt (1981). We now know that the exogenous processes are of the form:

$$(69) \quad \Delta p_t^* = \nu_0 + \nu_1 \Delta p_{t-1}^* + v_t$$

$$(70) \quad z_t = \delta_0 + \delta_1 z_{t-1} + x_t \quad .$$

Write equation (67) again as

$$(71) \quad y_{ct} = \beta + \gamma[\theta(v_t+x_t)+\bar{z}_t] + \lambda y_{ct-1} + \varepsilon_t,$$

$$\varepsilon_t = \rho\, \varepsilon_{t-1} + \omega_t .$$

An unrestricted version of equation (71) with the same variables and lags as in the exogenous processes is:

$$(72) \quad y_{ct} = \pi_0 + \pi_1 \Delta p_t^* + \pi_2 \Delta p_{t-1}^* + \pi_3 z_t + \pi_4 z_{t-1}$$

$$+ \lambda y_{ct-1} + \varepsilon_t , \quad \varepsilon_t = \rho\, \varepsilon_{t-1} + \omega_t .$$

The restrictions involved in estimating equation (71) rather than equation (72) are:

$$\frac{\pi_2}{\pi_1} = -\nu_1$$

$$\pi_1 = \pi_3$$

$$\frac{\pi_4}{\pi_1} = \frac{(1-\theta)}{\theta}\, \delta_1 \quad .$$

We already have estimates of the coefficients of equations (69), (70) and (71). To test the correctness of the 3 restrictions we also need estimates of the coefficients of the unrestricted equation, (72). Table 11 in Appendix A presents the estimated unrestricted output equation for each country. The estimation technique was the same as that used in estimating the restricted equation. The likelihood ratio statistic $-2(L_r - L_{ur})$ is distributed chi-square with degrees of freedom equal to the number of restrictions (in this case 3). L_r is the maximized log-likelihood value from the restricted equation while L_{ur} is that value for the unrestricted equation. The critical values are 7.81 and 6.25 at the 5% and 10% significance levels respectively. Values of the likelihood ratio statistic less than these critical values indicate that the null hypothesis that the restrictions are correct is not rejected at the relevant levels of significance. Clearly, the 10% significance level provides a more rigorous test than the 5% level.

The calculated chi-square statistics for the 3 restriction case are given in the first column of Table 10. In 10 of the 13 cases, the restrictions of the model are not rejected at the 5% significance level. Indeed, for 8 of these it is not rejected at the 10% significance level either. For Costa Rica, Jamaica, and Zambia, the

TABLE 10: LIKELIHOOD RATIO STATISTICS

Country	$\chi^2(3)$	$\chi^2(1)$
Costa Rica	19.90	19.70
Dominican Republic	6.96*	.07**
Fiji	6.20**	3.10*
The Gambia	3.10**	1.32**
Guyana	.64**	.48**
Honduras	2.96**	1.44**
Jamaica	16.42	15.92
Kenya	7.40*	2.12**
Malaysia	5.72**	4.22
Mauritius	5.16**	2.14**
Nicaragua	5.70**	.10**
Trinidad and Tobago	1.02**	.65**
Zambia	9.38	2.03**

NOTE: The first column, $\chi^2(3)$, gives the likelihood ratio statistic under the null hypothesis that the three overidentifying restrictions of the model are correct. The second column, $\chi^2(1)$, is for the null hypothesis that only unanticipated world price level shocks affect output. The critical values for 3 restrictions are 7.81 and 6.25 for the 5% and 10% significance levels respectively. The critical values for 1 restriction are 3.84 and 2.71. One asterisk indicates that the null hypothesis that the restrictions are correct is not rejected at the 5% level of significance. Two asterisks indicates non-rejection even at the 10% significance level.

restrictions of the model are rejected at the 5% level.[9]

It is appropriate to also consider some alternative economic models and their hypotheses about the data under examination. A common feature of rational expectations equilibrium models (including this one) is that only unanticipated nominal shocks have real effects. Keynesian models, on the other hand, with or without rational expectations, predict that the anticipated component of nominal variables will have real consequences as well. At the other extreme, full information or classical models often exhibit the absence of money illusion - nominal variables are perceived as such and have no real effects.[10]

As far as this model is concerned, the nominal variable is the foreign price level p_t^*. One way to assess the validity of these competing claims on the data is to estimate the following equation:

$$(73) \quad y_{ct} = \psi_0 + \psi_1 v_t + \psi_2 x_t + \gamma \bar{z}_t + \lambda y_{ct-1} + \varepsilon_t ,$$

$$\varepsilon_t = \rho \, \varepsilon_{t-1} + \omega_t .$$

This last equation is the same as (71) except that v_t and x_t are allowed to have different coefficients. Equation (73) is to be compared with the fully unrestricted equation, (72). The testable restriction is that

$\pi_2 = -\pi_1\nu_1$, that is, only unanticipated shocks to the world price level affect cyclical output in the small economy. Notice that this is one of the restrictions tested in the 3 restrictions case. The alternative hypothesis is that the Keynesian model,[11] or any model which has both anticipated and unanticipated movements in p_t^* affecting output, is correct. The unrestricted equation, (72), is identified with the Keynesian model. The (classical) hypothesis that even unanticipated shocks to p_t^* have no effect can be tested directly as the null hypothesis that the coéfficient on v_t, ψ_1, is equal to zero.

Table 12 in Appendix A presents the estimated equation, (73). The null hypothesis that only unanticipated movements in the world price level effect output is tested by calculating the likelihood ratio statistic for each country. These are given in the second column of Table 10. The null hypothesis is not rejected for 10 countries at the 5% significance level. For 9 of these it is not rejected at the 10% level either. The null hypothesis is rejected at the 5% level in the cases of Costa Rica, Jamaica, and Malaysia. Notice that Costa Rica and Jamaica had also rejected the fully restricted version of the model. Interestingly enough, the sign predictions of the model for ψ_1 and ψ_2 are satisfied for Costa Rica and Jamaica.

The sign and significance of the coefficient ψ_1 provides a test of the null hypothesis that a full information classical model is correct. Referring again to Table 12 in Appendix A, it can be seen that in 7 of the 13 cases the point estimate of ψ_1 is positive but only in one case is it significantly greater than zero. Among the 6 countries with negative ψ_1's, Zambia's is perversely significantly so. Therefore, in 11 cases, the estimate of ψ_1 is not significantly different from zero.

It seems therefore, that a full information equilibrium model is quite able to fit the facts. While, for most countries, we cannot reject the hypothesis that the rational expectations equilibrium model is correct, and that the specific prediction that only unanticipated world inflation shocks affect output is correct, we also cannot rule out the possibility that a classical model would do as well.

4.6 SUMMARY

This chapter tested the predictions for output of the model of a small, specialized economy that was formulated in earlier chapters. Unlike the tests in Lucas (1973) and Parkin, Bentley and Fader (1981), it was possible to combine the time-series and cross-country tests into one more powerful test.

Overall, the model fit fairly well and at least seems to be consistent with the data.[12] The restrictions implied by the rational expectations model are not rejected in most cases. Furthermore, the hypothesis that only unanticipated world price shocks affect output was not rejected in most cases. Interestingly enough, however, the evidence indicates that a full information classical model might do at least as well as the rational expectations model. The data turned up some interesting information as well. It was found that real terms of trade variance overwhelmingly dominates general world price variance. In addition, productivity shocks proved to be very important in practice with a significant proportion of the variance of output over the business cycle being determined by the variance of the productivity shock.

CHAPTER 4 - FOOTNOTES

1. The data for 1975 were used for this purpose.

2. The identification procedure was done using a program PDQ. The output includes sample autocorrelations and partial autocorrelations with their corresponding standard errors, as well as the variance of each series.

3. Estimation was by a program EST which uses Marquardt's iterative procedure, which amounts to a compromise between the methods of Gauss-Newton and steepest descent. Initial guess values of the parameters were needed to start the iterations. For more details see Nelson (1973).

4. Nelson (1973) gives the following expression as Bartlett's approximation of the variance of the jth autocorrelation coefficient, V_i:

$$V_i = \frac{1}{T}\,[1 + 2 \sum_{i=1}^{q} r_i^2] \quad j > p ,$$

where r_i is the ith autocorrelation coefficient, T is the sample size, and p is the order of the moving-average process generating the residuals.

5. The Q statistic is given by

$$Q = T \sum_{j=1}^{K} r_j^2$$

where r_j is the jth sample autocorrelation, T is the sample size, and K the number of lags. The Q statistic is approximately distributed chi-square with (k-p-q) degrees of freedom, where q is number of autoregressive coefficients and p the number of moving average coefficients. The program EST output presents Q values for K = 12 and 24 lags.

6. Q(12) is rather high for The Gambia, though it does not exceed the critical level. The fourth and sixth lag autocorrelations of the residuals were almost significantly greater than and less than zero respectively. Efforts to identify a better model were however unsuccessful. In the case of Costa Rica, I had to restrict the number of observations in order to achieve convergence of the estimates. The problem here was that for a number of years the terms of trade were constant. This constancy also cropped up in the Kenyan data.

7. Efforts to obtain meaningful standard errors for θ proved unsuccessful. It is possible to obtain a type of confidence interval for θ using the F or Beta distributions. These confidence intervals,

however, depend only on the sample sizes used in estimating σ_v^2 and σ_x^2. We can state the obvious however: the estimate of θ is more precise the larger the sample size used in estimating σ_x^2, since σ_v^2 is common to all countries.

8. A linear trend was used for each country. However, a specification search was carried out on the trend. In some cases, for example Jamaica, Zambia and Malaysia, the time-series for output seemed to indicate that a quadratic trend might be better. In the case of Zambia, it also seemed that a no trend specification might be better. There is also the possibility that estimating the trend simultaneously with the output equation might lead to an improvement in the fit. When these alternative specifications were tried the estimates almost always worsened or remained the same. Thus the linear trend seemed to be adequate.

9. The behaviour of output in Jamaica and Costa Rica is interesting. In the case of Jamaica, output shows a distinct downward trend after 1973, presumably associated with political factors. During this period, output seems to have reacted to forces other than those dealt with in this thesis. If that is the case

then the model indeed is rejected by the Jamaican data. In the case of Costa Rica, output stays very close to a linear trend, despite significant terms of trade fluctuations.

10. For a good discussion of the relation of classical and Keynesian models to the new classical or rational expectations equilibrium models, see Parkin (1982).

11. It should be emphasized that the Keynesian model is never tested as the null hypothesis. We do test the rational expectations equilibrium model and a restriction of the classical model as null hypotheses. The Keynesian model is identified with the alternative hypothesis, equation (72).

12. It is my view that the model fit especially well, given the quality of the data and the political situations in many of the countries in the sample. Furthermore, many countries in the sample obtained political independence during the time period covered. This was often associated with nationalization of the export sectors. This usually had some impact on the responsiveness to market forces of production in these sectors.

CHAPTER 5

CONCLUSION

The stated purpose of this thesis was to formulate and test a rational expectations equilibrium model of output determination in the small, open, specialized economy. This model was intended to explain cyclical fluctuations in output in such economies.

The theoretical model has the decision rules of agents being based on an underlying explicit dynamic optimization problem, in a context which captures several key features of small, less developed countries. The model economy produces a single good for export and imports consumption goods, both at given world prices, output is produced using labour as the only variable input, there are persistent shocks to the production function, and it is costly to rapidly adjust employment.

The predictions of the model for the behaviour of output are similar in several ways to those of standard neoclassical models. First, output is decomposed into a natural rate and a cyclical component. Second, cyclical output is predicted to follow a stochastically disturbed first-order difference equation. Third, only the unanticipated component of nominal variables effect output.

The model predicts that the output process will be disturbed by unanticipated changes in the terms of trade and the world price level. In addition, the prior expected value of the terms of trade as well as a persistent shock to the productivity of labour drive output over time. Furthermore, the size of the impact of the world price level and terms of trade shocks (the inverse of the slope of the Phillips curve in world inflation-output space) is predicted to depend in a systematic way on the variances of these shocks.

These predictions were tested for 13 small economies and found some, though fairly limited, support in the data. The restrictions implied by the model were not rejected for 10 of the 13 countries in the sample, thereby indicating that it is possible to model output fluctuations in these economies as equilibrium phenomena. The hypothesis that only unanticipated world price shocks affect output could not be rejected in 10 cases against a simple Keynesian alternative. However, the null hypothesis that a full information classical is correct could not be rejected in 11 cases.

It was also found that real variance predominates over nominal variance in explaining the cycle. This is related to the success of the classical model which is a real model.

The variance of the terms of trade disturbance and that of the productivity disturbance were prime contributors to the variance of cyclical output. This is interesting because recent work on business cycles by Kydland and Prescott (1982), and Long and Plosser (1983), emphasize and find support for real theories of the business cycle in closed economies. Certainly, the productivity shocks in this model play a role similar to those in Kydland and Prescott (1982). This thesis provides some evidence that, at least for small export-oriented economies, real factors are the main generators of output fluctuations.

The model formulated in this thesis also makes predictions about the impact of the foreign shocks and the productivity shock on the balance of payments under fixed exchange rates and the domestic price level and exchange rate under flexible exchange rates. These predictions are however largely contingent upon the predictions of the output equation being correct. The theoretical model predicts that a flexible exchange rate provides insulation from foreign shocks only when foreign nominal variance is predominant. The actual importance of real variance in the sample means that the above condition does not hold for the countries studied.

While the model finds some support in the data, it is clear that this support is not strong. Indeed, the model is rejected outright for 3 countries and the estimates of the coefficients are weak in several others. It is all too easy to blame the data but the output and terms of trade data was often judged to be of low quality. Another factor at work weakening the results might be political instability and the increased government ownership of the export sectors in several of the countries used. An important factor could be that the use of annual data does not allow for the fact that production time varies from product to product, and from country to country.

Future research should, first, allow for capital mobility and interest rate effects to better model the monetary sector. Second, the government sector should be modelled more richly. Third, the model of the individual small economy should be linked up to the rest of the world explicitly. The model formulated in this thesis deals with the individual experiment: export and import prices are given and not determined in the model. An extension of the model would deal with the market experiment: export and import prices would be determined. The purpose of such a model would be the modelling of the interlinkages between industrialized and less developed economies with a view towards explaining fluctuations in output, employment, the balance of payments, prices and exchange rates in the less developed economies. An integral part of the analysis would be the modelling of international commodity markets and explaining fluctuations in commodity prices, the less developed countries' export prices and their terms of trade.

APPENDIX A

THE LESS RESTRICTED OUTPUT EQUATIONS

TABLE 11: THE UNRESTRICTED OUTPUT EQUATION

Country	π_0	π_1	π_2	π_3	π_4	λ	R^2	D.W.	L	T
Costa Rica	-.479	-.529	-.122	.155	-.045	1.944	.91	2.38	49.19	15
	(.130)*	(.164)*	(.149)	(.031)*	(.026)	(.264)*				
Dominican Republic	-3.606	1.619	-1.196	.290	.566	-.125	.41	1.32	20.80	20
	(1.384)*	(1.551)	(1.801)	(.204)	(.205)*	(.238)				
Fiji	-2.127	.858	-1.993	.351	.174	.207	.76	1.85	34.88	19
	(.734)*	(.697)	(.806)*	(.116)*	(.128)	(.234)				
The Gambia	-.727	-2.098	-2.470	.212	-.054	.538	.48	2.30	18.62	20
	(.466)	(1.480)	(1.550)	(.129)	(.124)	(.208)*				
Guyana	-.259	-.126	.596	.123	-.067	.119	.21	1.83	26.56	20
	(.537)	(1.523)	(1.571)	(.164)	(.158)	(.305)				
Honduras	-.740	-.180	.409	.045	.102	.979	.80	2.22	45.60	20
	(.359)	(.452)	(.435)	(.071)	(.061)	(.148)*				
Jamaica	.154	-.858	-.464	-.004	-.012	1.182	.94	1.96	39.26	21
	(.394)	(.773)	(.786)	(.075)	(.109)	(.084)*				
Kenya	-.263	.314	-.817	-.344	.091	-.395	.51	1.39	42.06	16
	(.433)	(.300)	(.379)	(.640)	(.055)	(.239)				
Malaysia	-1.697	.328	.329	.511	-.174	.467	.76	1.82	51.29	26
	(.703)*	(.546)	(.510)	(.081)*	(.149)	(.238)				
Mauritius	-1.671	.950	-1.432	.166	.241	.309	.91	2.37	27.98	15
	(.538)*	(.712)	(.823)	(.094)	(.126)	(.227)				
Nicaragua	-.225	1.222	-1.254	.154	-.110	.892	.53	1.56	40.24	20
	(.725)	(.574)	(.661)	(.114)	(.098)	(.243)*				
Trinidad & Tobago	-.470	.175	.512	.140	-.031	.477	.53	1.92	50.79	27
	(.265)	(.767)	(.725)	(.064)*	(.069)	(.201)*				
Zambia	-1.112	-3.138	3.558	.377	-.143	.720	.90	2.01	30.56	22
	(.394)*	(1.100)*	(1.312)*	(.102)*	(.084)	(.124)*				

TABLE 12: THE OUTPUT EQUATION WITH ONE RESTRICTION

Country	ψ_0	ψ_1	ψ_2	γ	λ	R^2	D.W.	L	T
Costa Rica	-.459 (.398)	.118 (.283)	.062 (.058)	.094 (.083)	.540 (.516)	.24	1.43	39.34	15
Dominican Republic	-6.554 (2.214)*	1.577 (1.492)	.304 (.188)	1.570 (.531)*	-.121 (.230)	.41	1.32	20.77	20
Fiji	-2.490 (.701)*	1.019 (.610)	.260 (.091)*	.594 (.179)*	-.053 (.229)	.53	1.86	33.33	19
The Gambia	-.728 (.616)	-1.776 (1.494)	.183 (.129)	.164 (.137)	.551 (.211)*	.41	2.18	17.96	20
Guyana	-.394 (.501)	-.193 (1.483)	.162 (.145)	.095 (.122)	.112 (.298)	.19	1.86	26.32	20
Honduras	-.645 (.345)	-.184 (.450)	.023 (.069)	.131 (.070)	.939 (.160)*	.75	2.01	44.88	20
Jamaica	-.717 (1.031)	.637 (1.023)	.025 (.102)	.162 (.241)	.941 (.251)*	.51	1.90	31.30	21
Kenya	-.604 (.326)	.490 (.280)	.010 (.055)	.120 (.067)	-.355 (.253)	.41	1.41	41.00	16
Malaysia	-1.540 (.983)	-.102 (.566)	.510 (0.93)*	.315 (.200)	.358 (.246)	.69	1.85	49.18	26
Mauritius	-1.668 (.601)*	.916 (.739)	.111 (.084)	.400 (.144)*	.487 (.171)*	.89	2.35	26.91	15
Nicaragua	-.204 (.521)	1.241 (.551)*	.171 (.091)	.040 (.104)	.886 (.237)*	.52	1.52	40.19	20
Trinidad & Tobago	-.525 (.209)*	-.192 (.605)	.162 (.054)*	.135 (.053)*	.500 (.197)*	.51	1.88	50.47	27
Zambia	-.570 (.442)	-2.616 (1.056)*	.288 (.079)*	.122 (.094)	.798 (.110)*	.89	1.89	29.55	22

APPENDIX B

DATA SOURCES AND GENERATION

TIME-SERIES PLOTS

THE DATA

APPENDIX B

B.1 DATA SOURCES AND GENERATION

The sources of the data were the International Financial Statistics (IFS) Yearbook (1980 and 1982), and the International Financial Statistics Supplement on Trade Statistics (1982). These data sources have the advantage of uniformity of method and base years. All indices use 1975 as the base year.

A world consumer price index, series 00164X from IFS, was used as a proxy for the world price level common to all countries. I also tried a price index for the industrial countries but this gave results which were almost identical to those obtained using the world consumer price index. The world consumer price index is calculated as a geometric mean of country indices, weighted by GDP in U.S. dollars. One property of a geometric mean is that, unlike an arithmetic mean, a geometric mean is not unduly influenced by prices from countries with extreme inflation rates. Moreover, if all countries have constant but different inflation rates, the geometric mean will have a constant rate of growth.

For the terms of trade series for each country, I made as much use as possible of a database from the IFS Supplement on Trade Statistics. This contains previously unpublished terms of trade data for some countries. However, terms of trade data had to be generated for some countries. For Jamaica and Zambia, an export unit value index (series 74 of IFS) was converted to U.S. dollars by an exchange rate index (derived from series rf, IFS). The resultant series was deflated by the world price index, thereby generating a terms of trade index. This use of the world price index as a proxy for an import price index is justified by the casual observation that import prices for many developing countries move together. In fact, this observation was used in generating the new terms of trade indices in the Trade Supplement.

For Costa Rica and Guyana, I generated an export price index by taking a weighted average of the export price sub-indices, the weights being the relative shares in the sum of the values of the various exports. In The Gambia and Trinidad and Tobago, the dominance of a single good in exports and the unavilability of price data for the other goods meant that the price index for the dominant good was used as the export price index. For Trinidad and Tobago, the price of petroleum at Venezuela, series 76aa IFS, was used, while for The Gambia, the price of groundnut products, series 74bh IFS, was the one used. For Costa Rica and Guyana, 1976 rather than 1975 weights were used because it was judged that 1976 was a more representative year in terms of the weights. For each of these 4 countries, after the export price index was generated, a procedure identical to that used to calculate the terms of trade indices for Jamaica and Zambia was followed.

All output data was obtained from IFS. For most countries the real GDP series 99b.p in constant 1975 dollars was converted to U.S. dollars at the exchange rate prevailing in 1975. For Fiji, The Gambia, Guyana, and Trinidad and Tobago, there were no real GDP series and I resorted to deflating nominal GDP (series 99b) by the domestic price index (series 84), and then converting to U.S. currency.

B.2 TIME-SERIES PLOTS

FIGURE 2

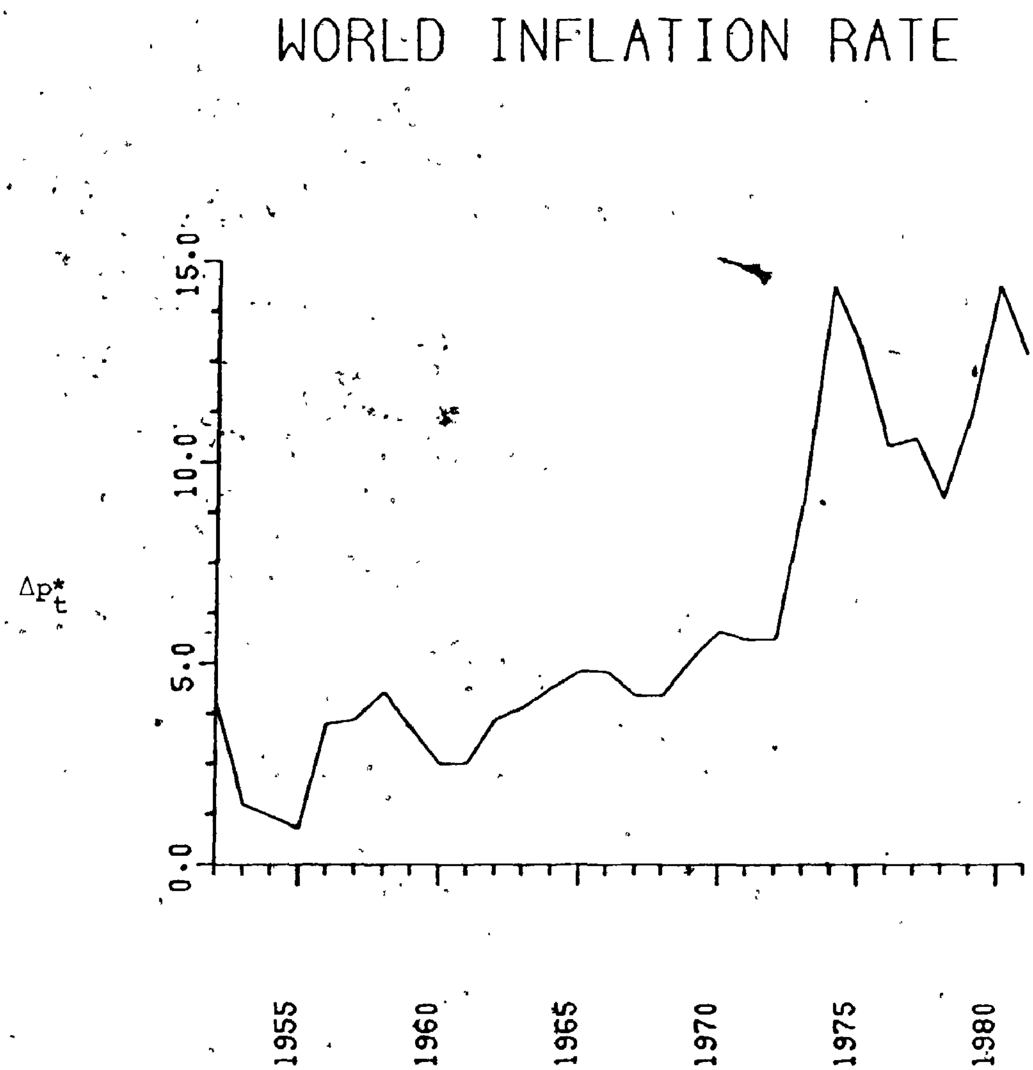


FIGURE 3

WORLD PRICE SURPRISE

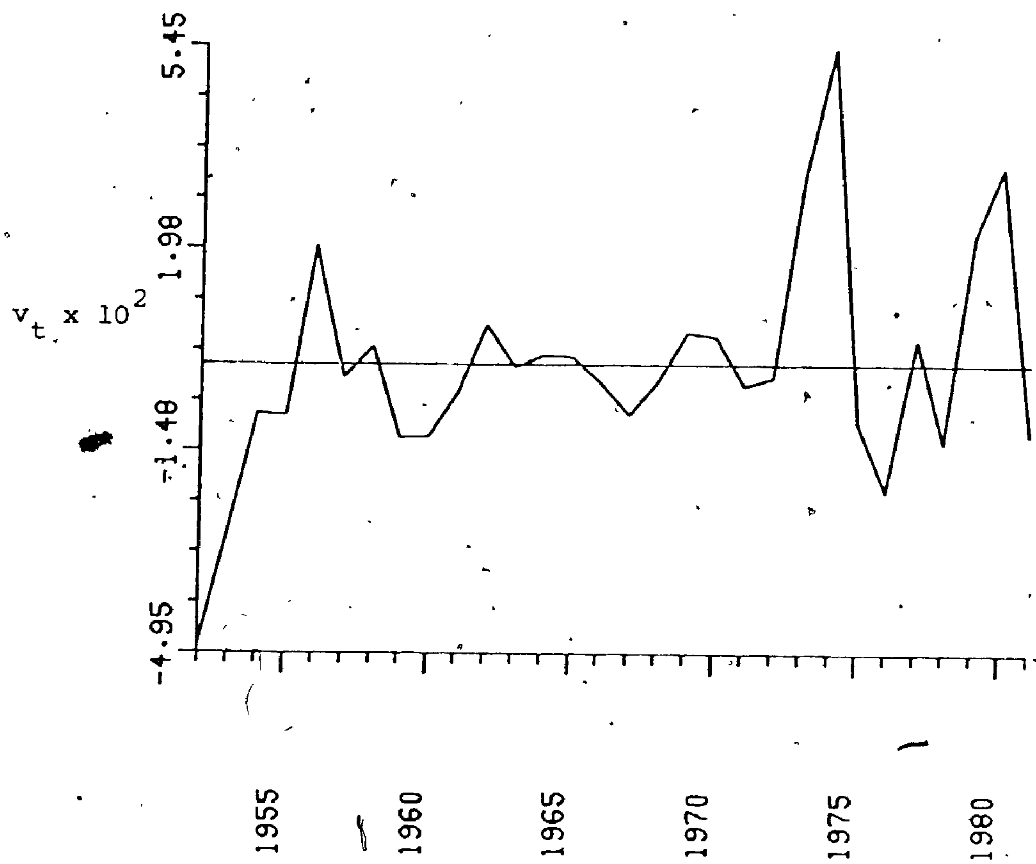


FIGURE 4

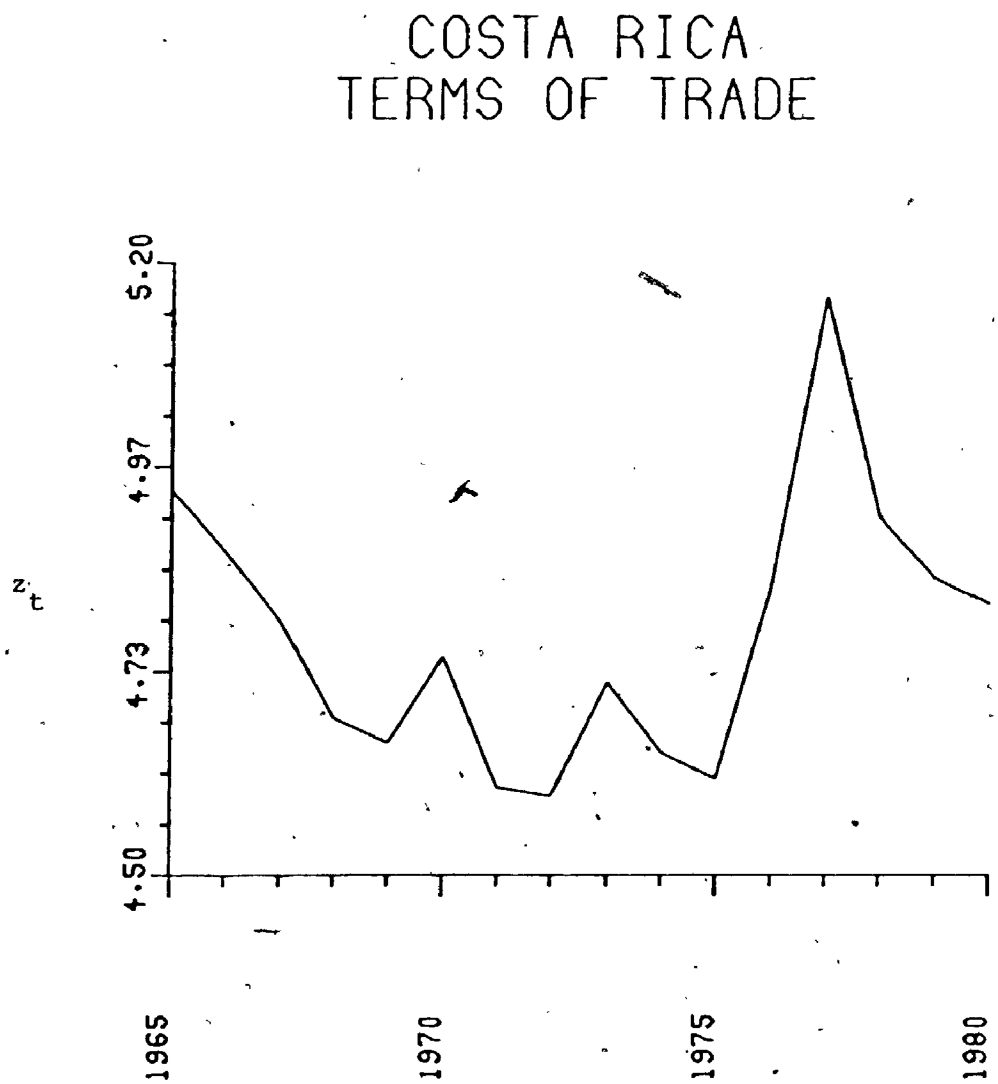

COSTA RICA
TERMS OF TRADE
5.20
4.97
4.73
4.50
z_t
1965
1970
1975
1980

FIGURE 5

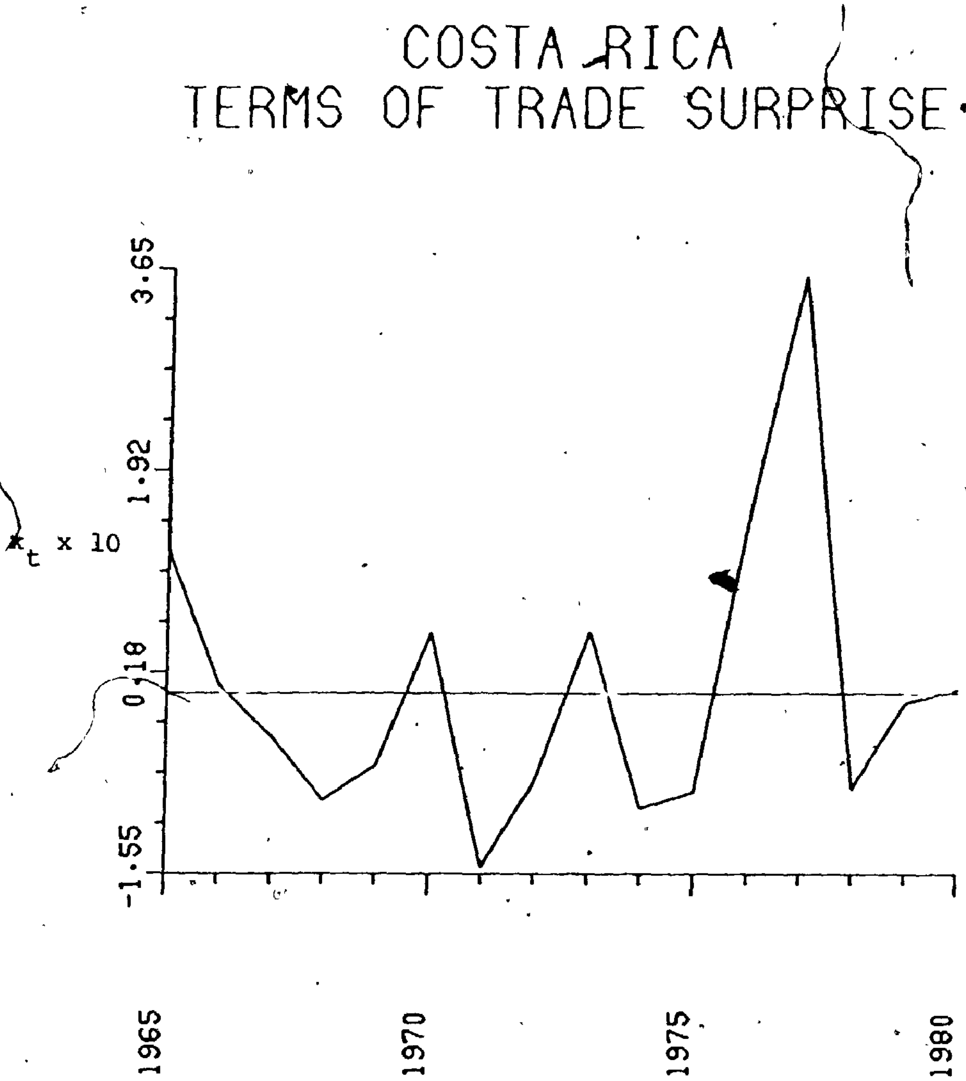

COSTA RICA
TERMS OF TRADE SURPRISE
3.65
1.92
x_t x 10
0.18
-1.55
1965
1970
1975
1980

FIGURE 6

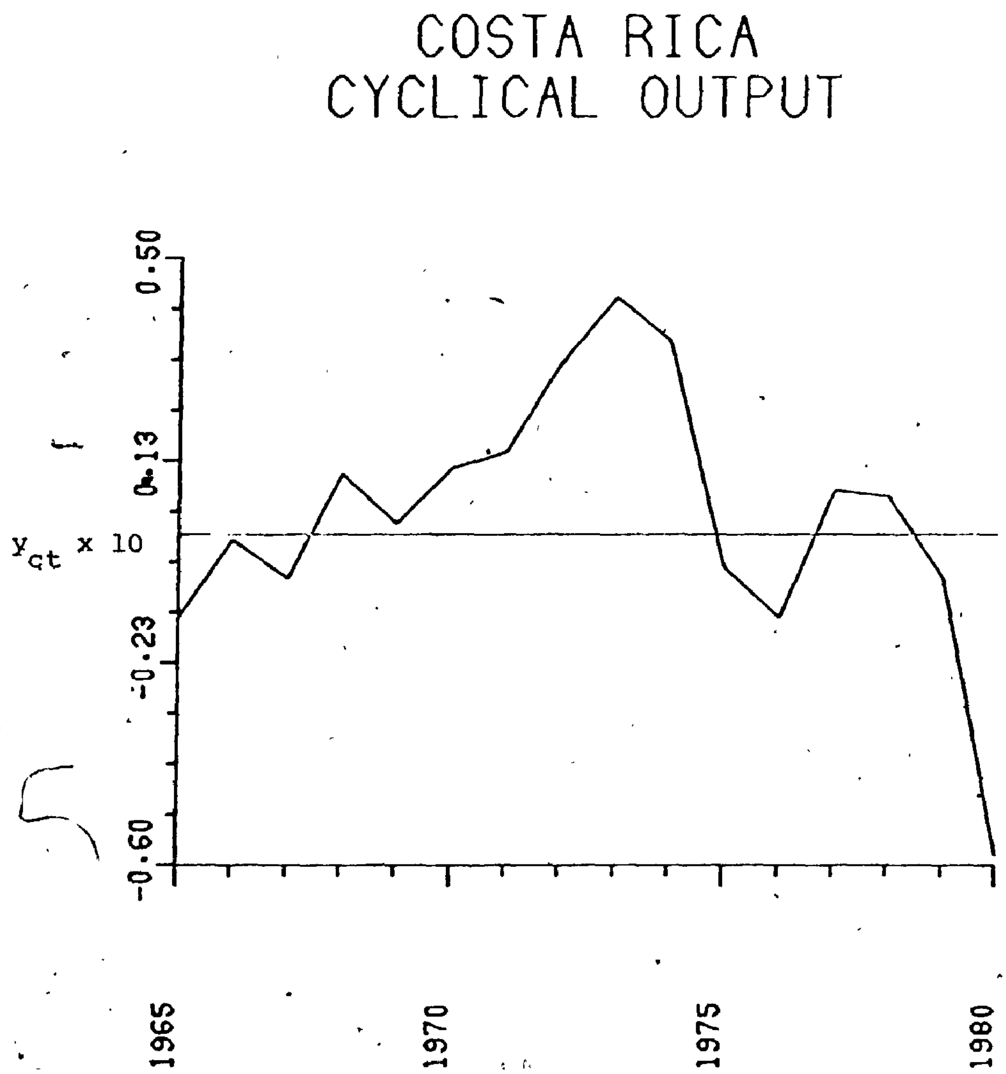

COSTA RICA
CYCLICAL OUTPUT
0.50
0.13
y_{ct} x 10
-0.23
-0.60
1965
1970
1975
1980

FIGURE 7

DOMINICAN REPUBLIC
TERMS OF TRADE

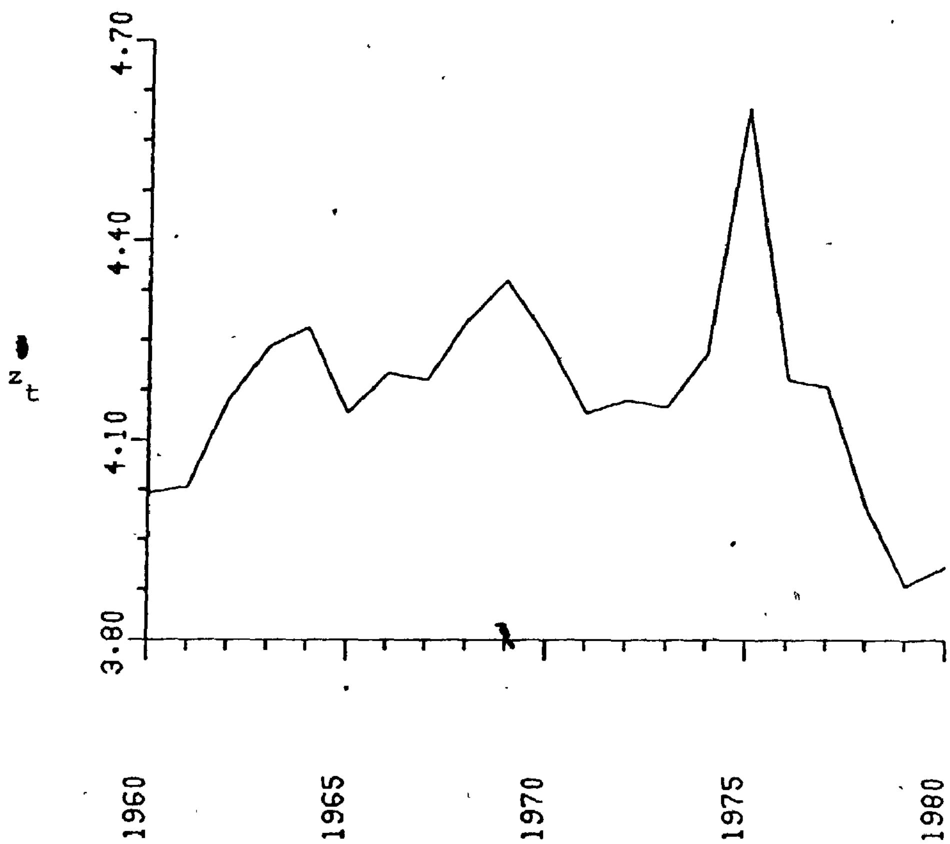


FIGURE 8

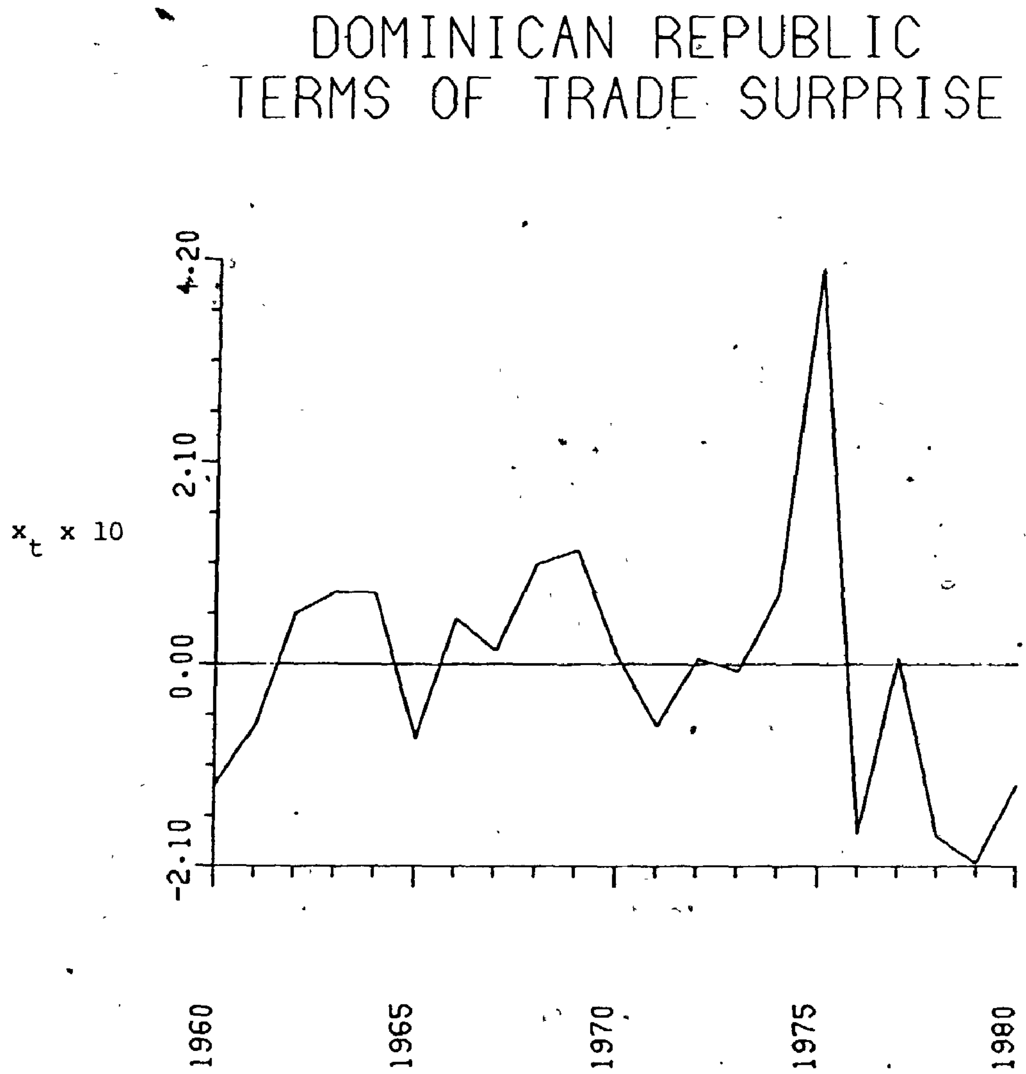

DOMINICAN REPUBLIC
TERMS OF TRADE SURPRISE
x_t x 10
4.20
2.10
0.00
-2.10
1960
1965
1970
1975
1980

FIGURE 9

DOMINICAN REPUBLIC
CYCLICAL OUTPUT

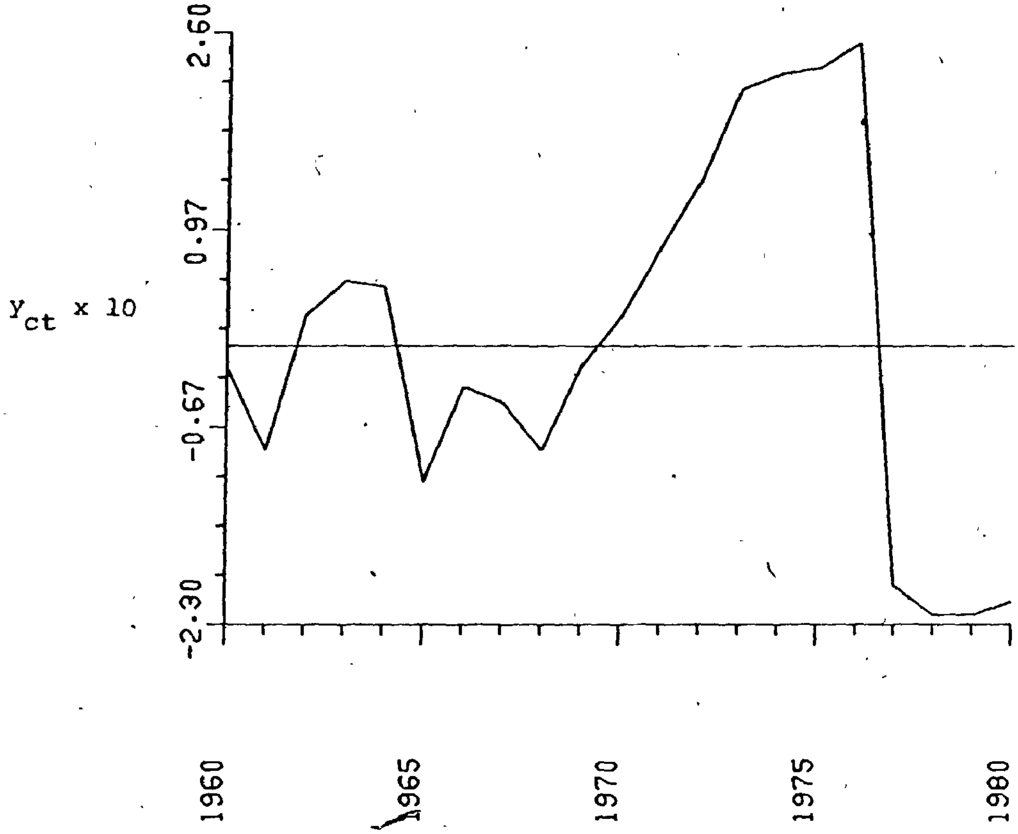


FIGURE 10

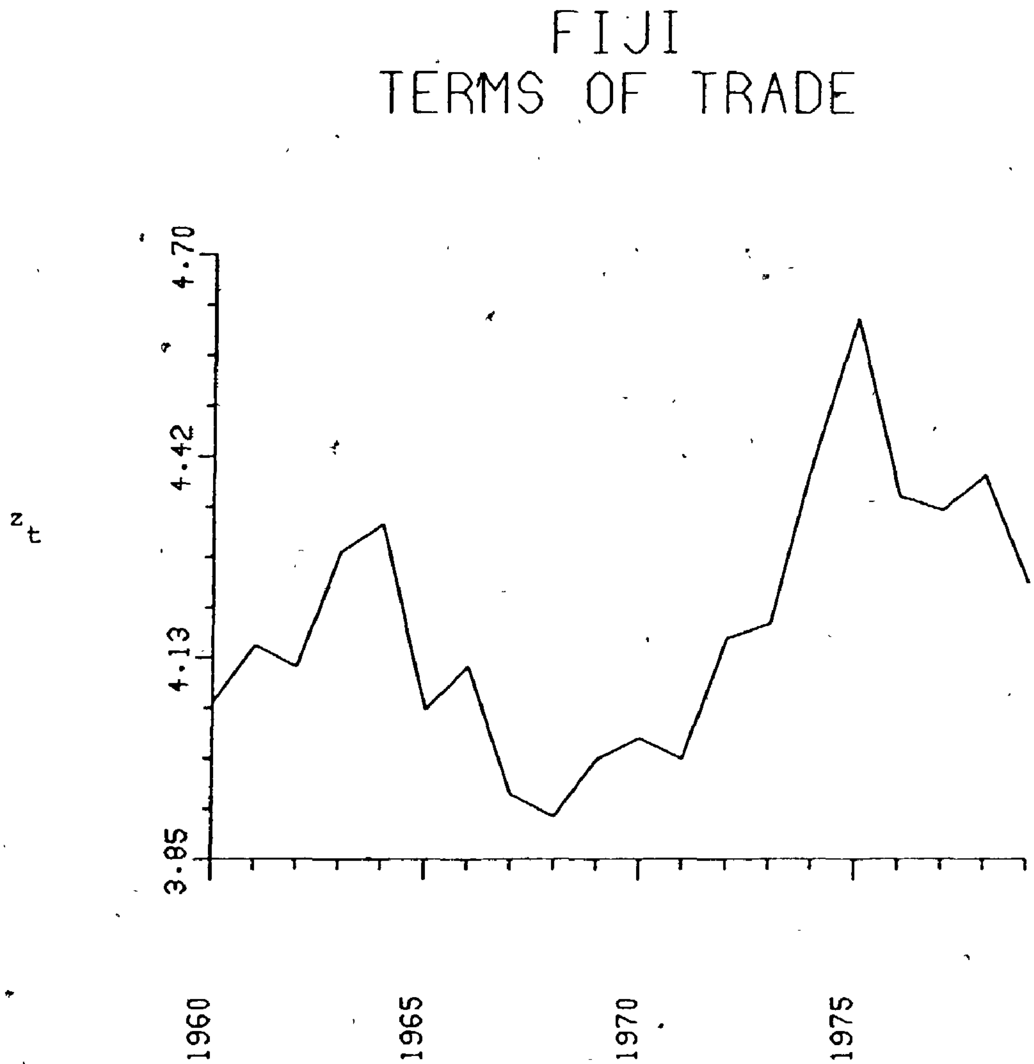


FIGURE 11

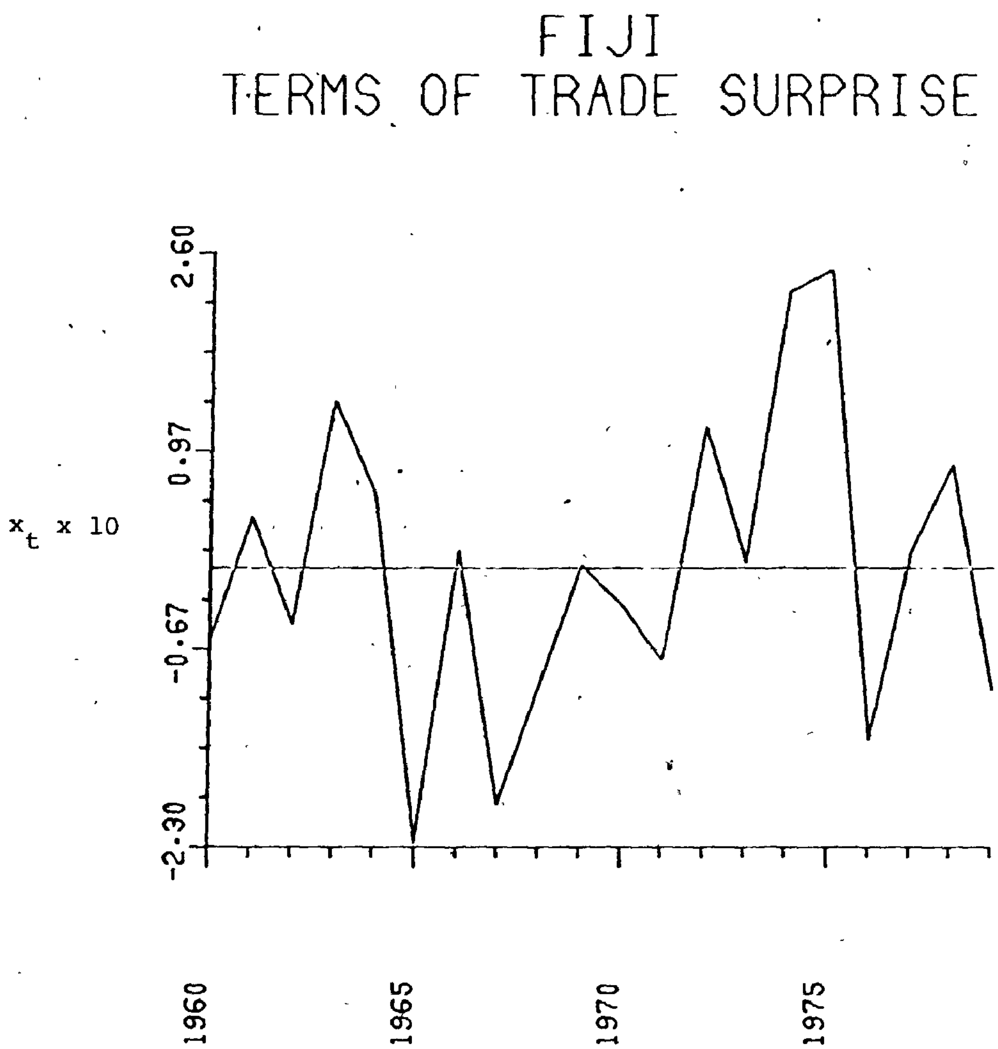

FIJI
TERMS OF TRADE SURPRISE
2.60
0.97
-0.67
-2.30
x_t x 10
1960
1965
1970
1975

FIGURE 12

FIJI
CYCLICAL OUTPUT

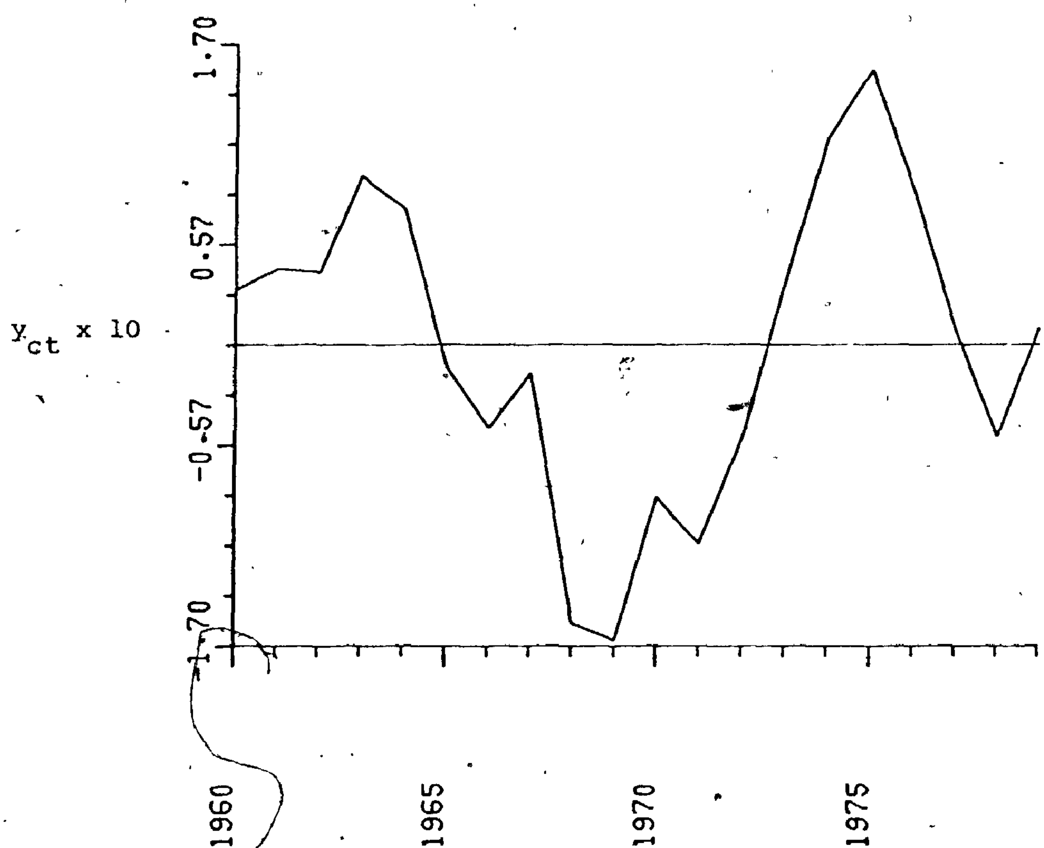


FIGURE 13

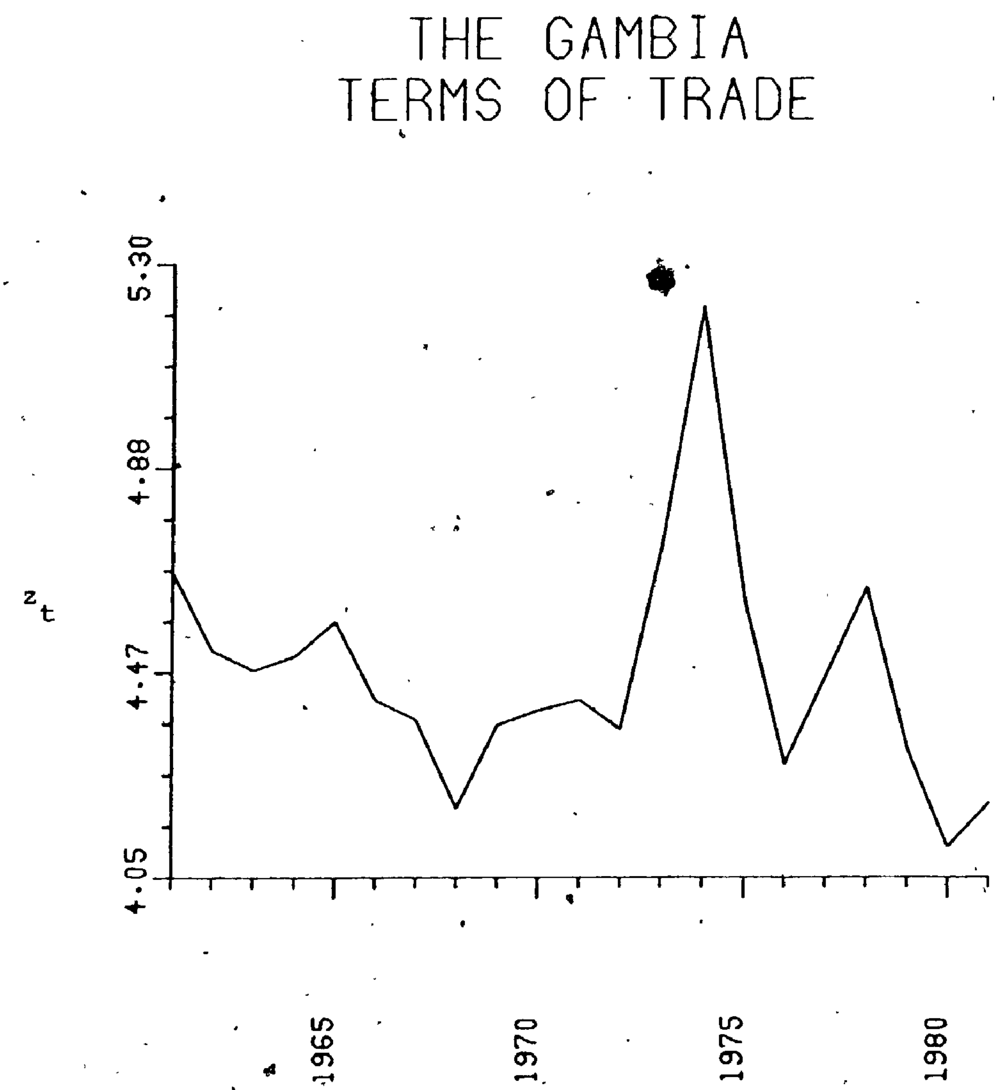

THE GAMBIA
TERMS OF TRADE
5.30
4.88
4.47
4.05
z_t
1965
1970
1975
1980

FIGURE 14

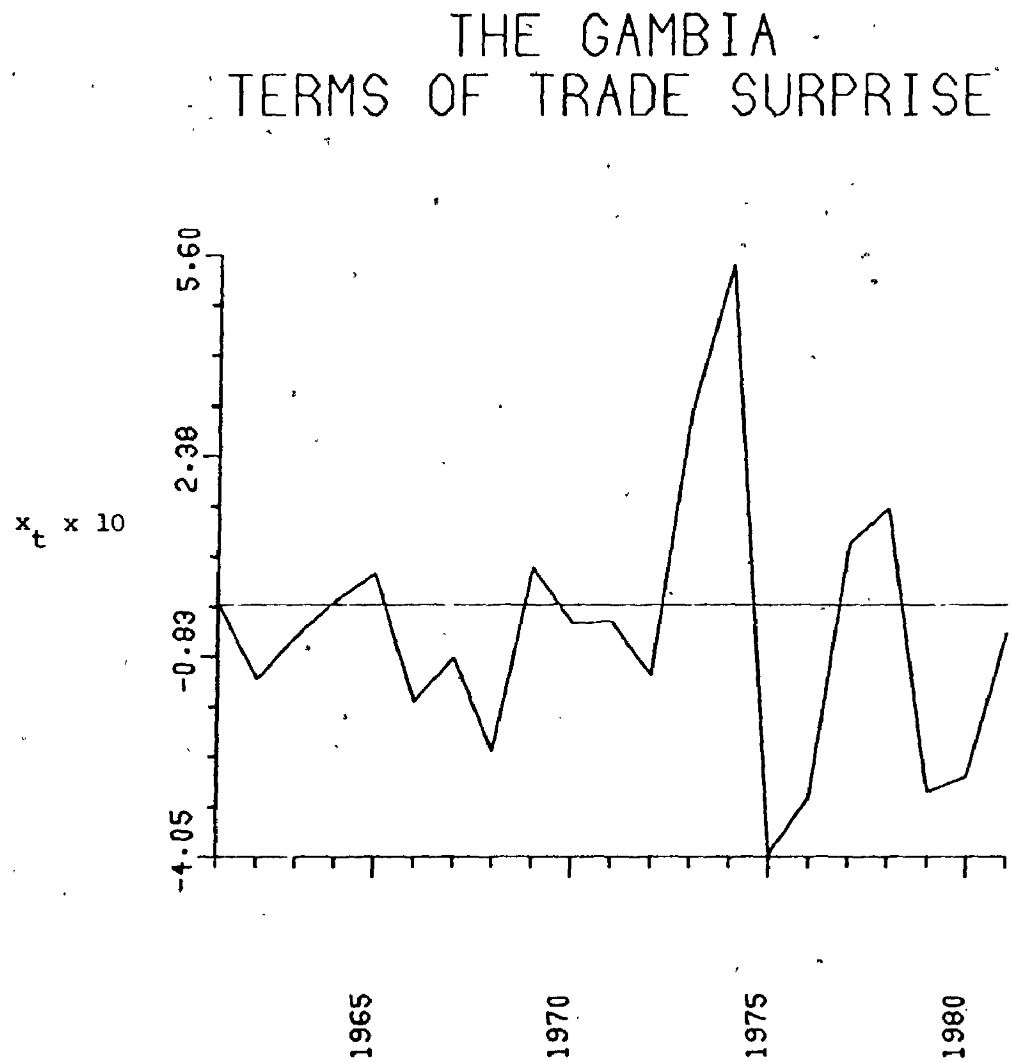

THE GAMBIA
TERMS OF TRADE SURPRISE
5.60
2.38
-0.83
-4.05
x_t x 10
1965
1970
1975
1980

FIGURE 15

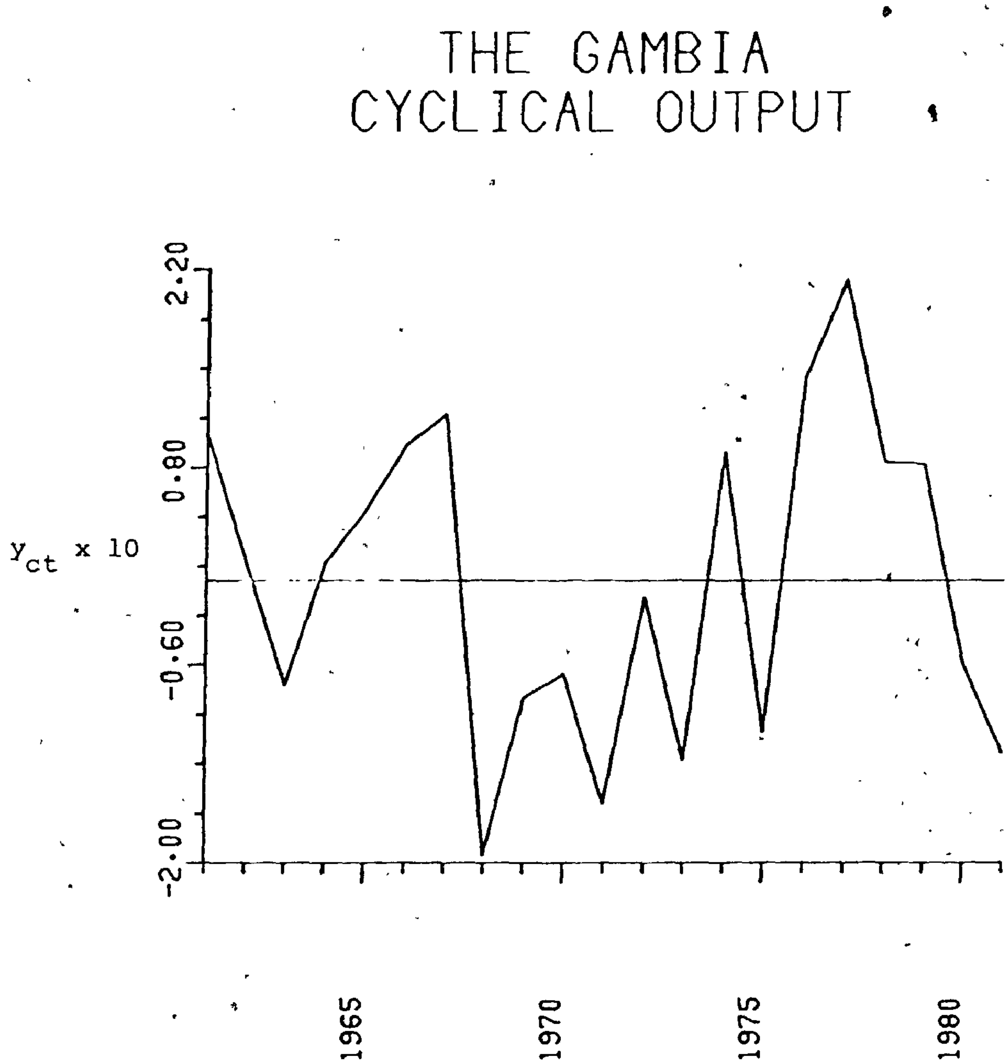

THE GAMBIA
CYCLICAL OUTPUT
2.20
0.80
-0.60
-2.00
y_{ct} x 10
1965
1970
1975
1980

FIGURE 16

GUYANA
TERMS OF TRADE

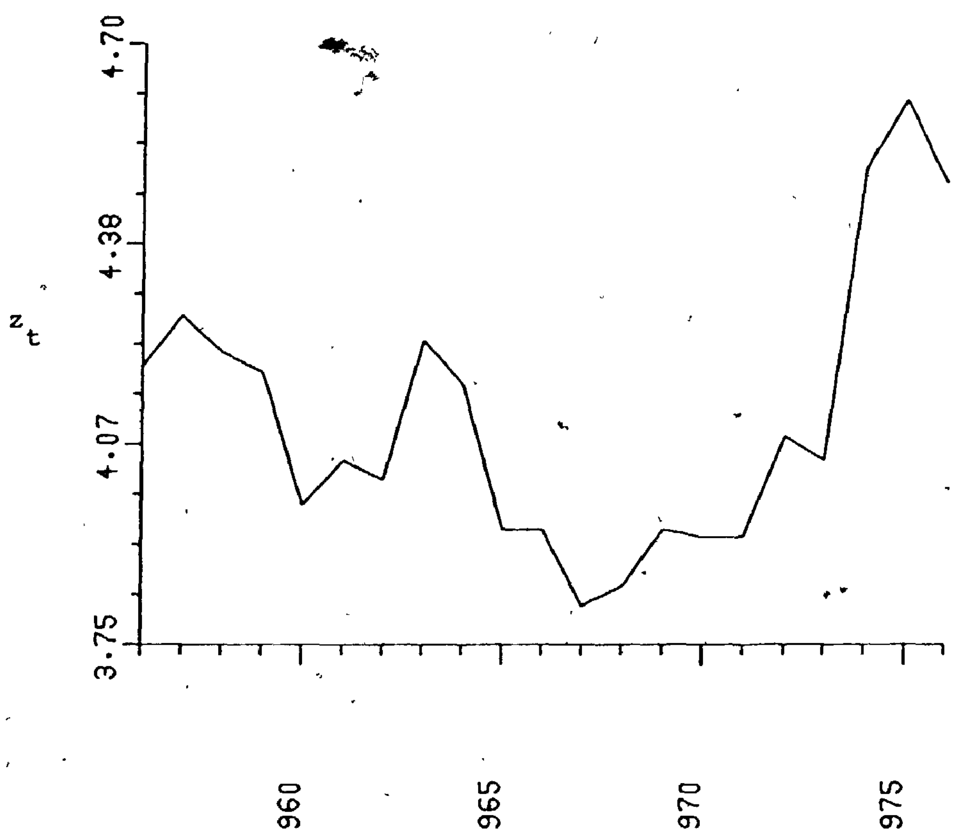


FIGURE 17

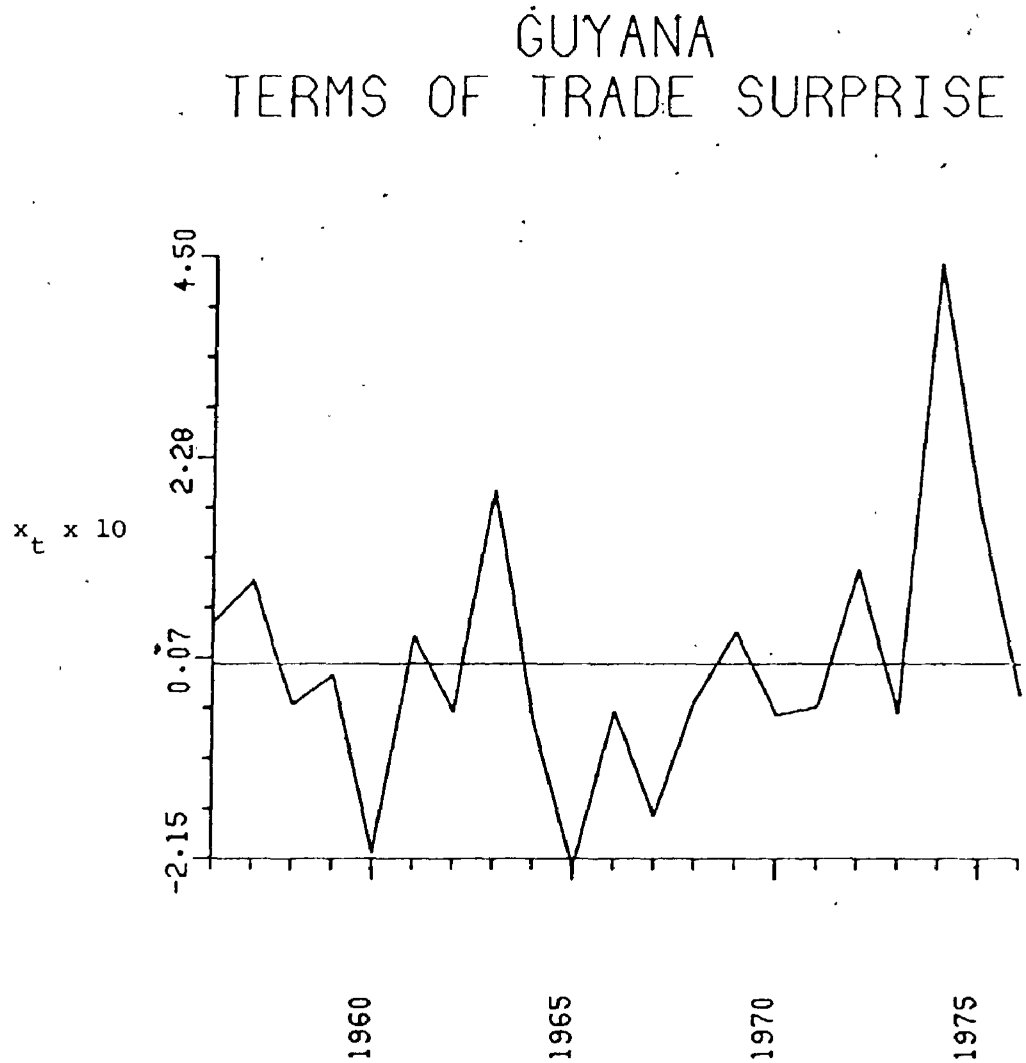

GUYANA
TERMS OF TRADE SURPRISE
4.50
2.28
0.07
-2.15
x_t x 10
1960
1965
1970
1975

FIGURE 18

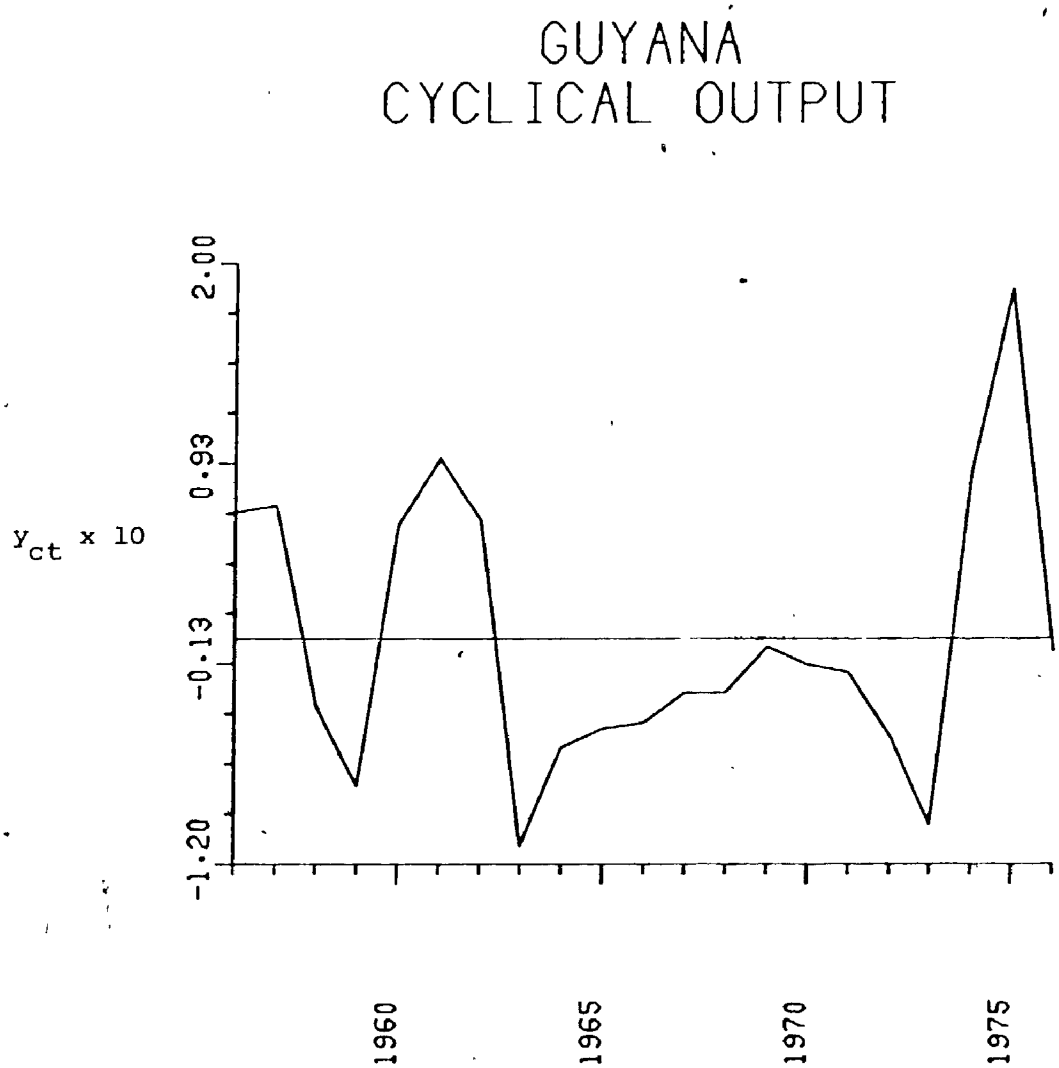

GUYANA
CYCLICAL OUTPUT
y_{ct} x 10
2.00
0.93
-0.13
-1.20
1960
1965
1970
1975

FIGURE 19

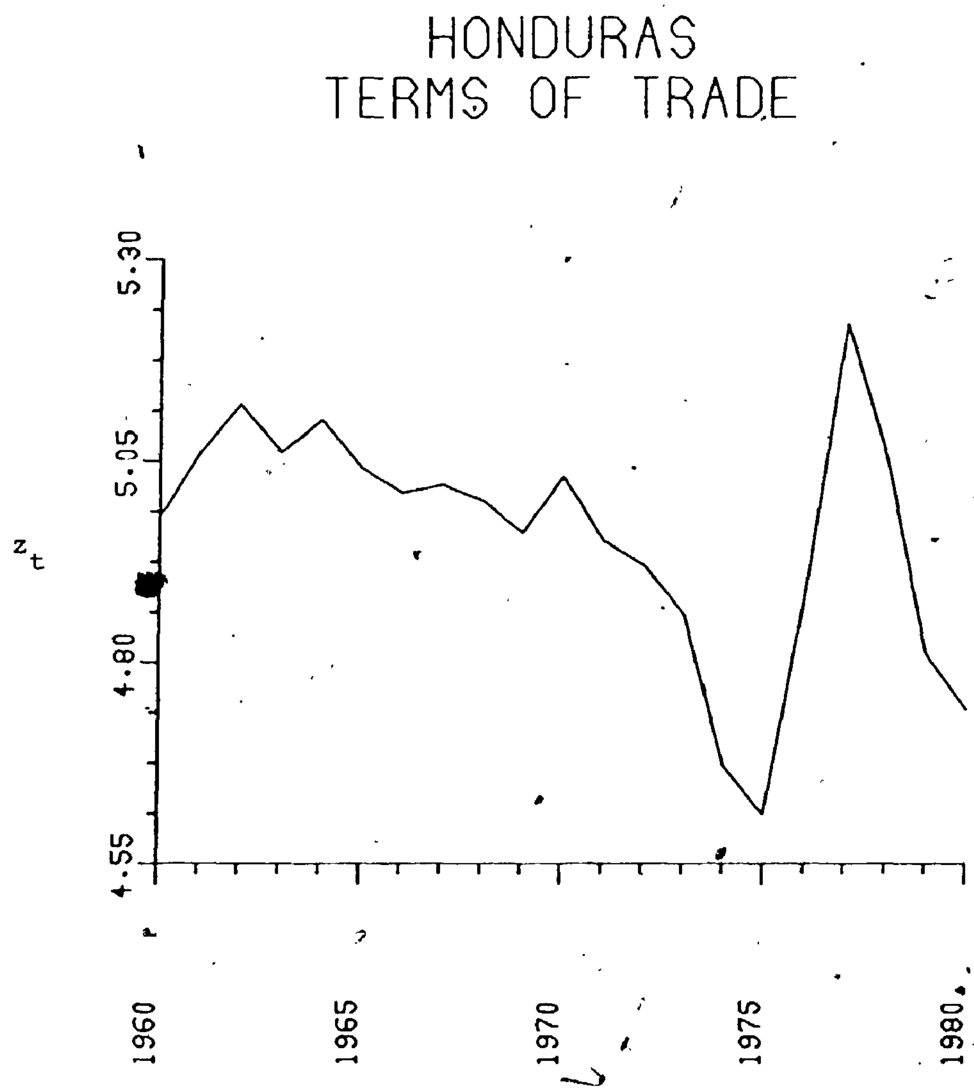

HONDURAS
TERMS OF TRADE
5.30
5.05
4.80
4.55
z_t
1960
1965
1970
1975
1980

FIGURE 20

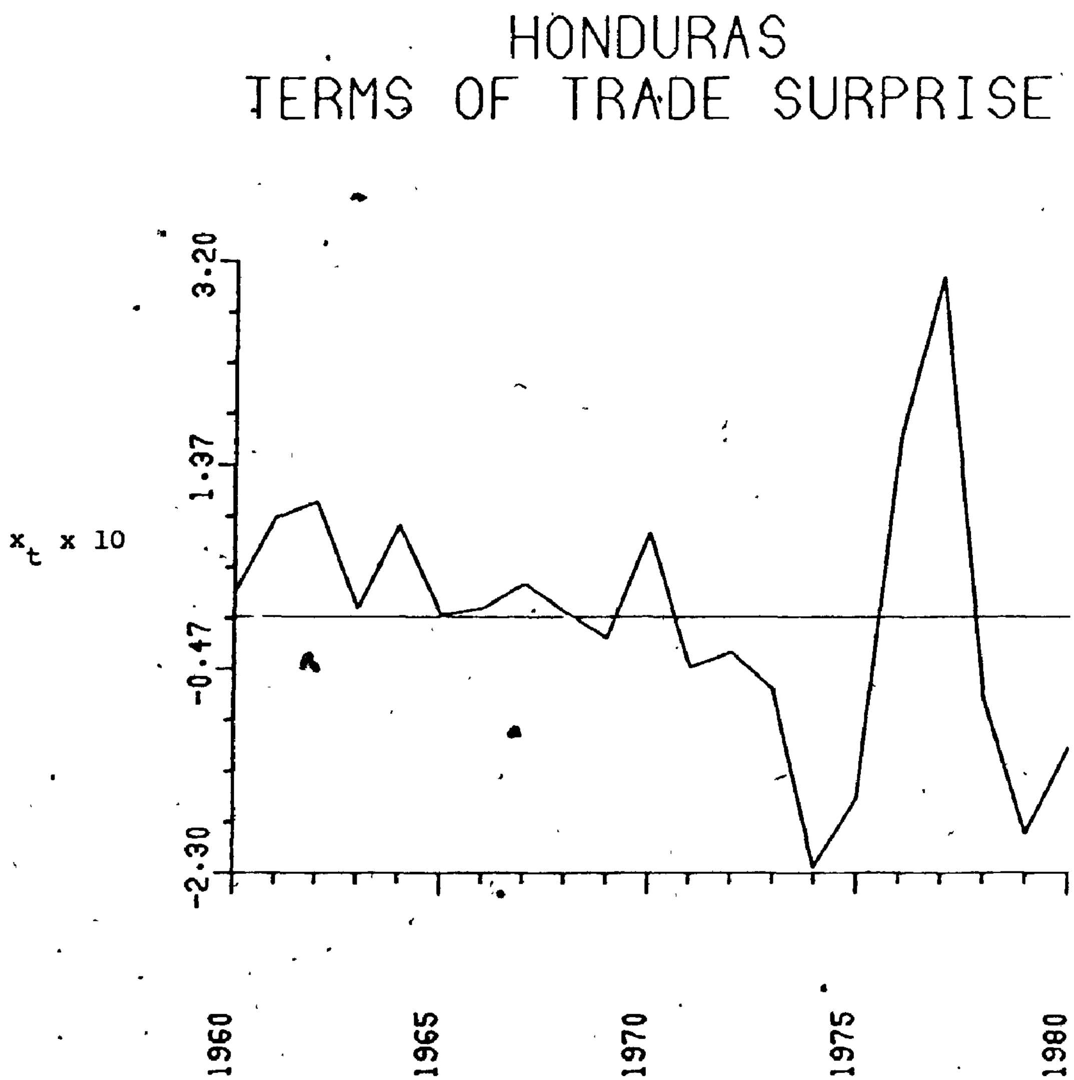

HONDURAS
TERMS OF TRADE SURPRISE
3.20
1.37
-0.47
-2.30
x_t x 10
1960
1965
1970
1975
1980

FIGURE 21

HONDURAS
CYCLICAL OUTPUT

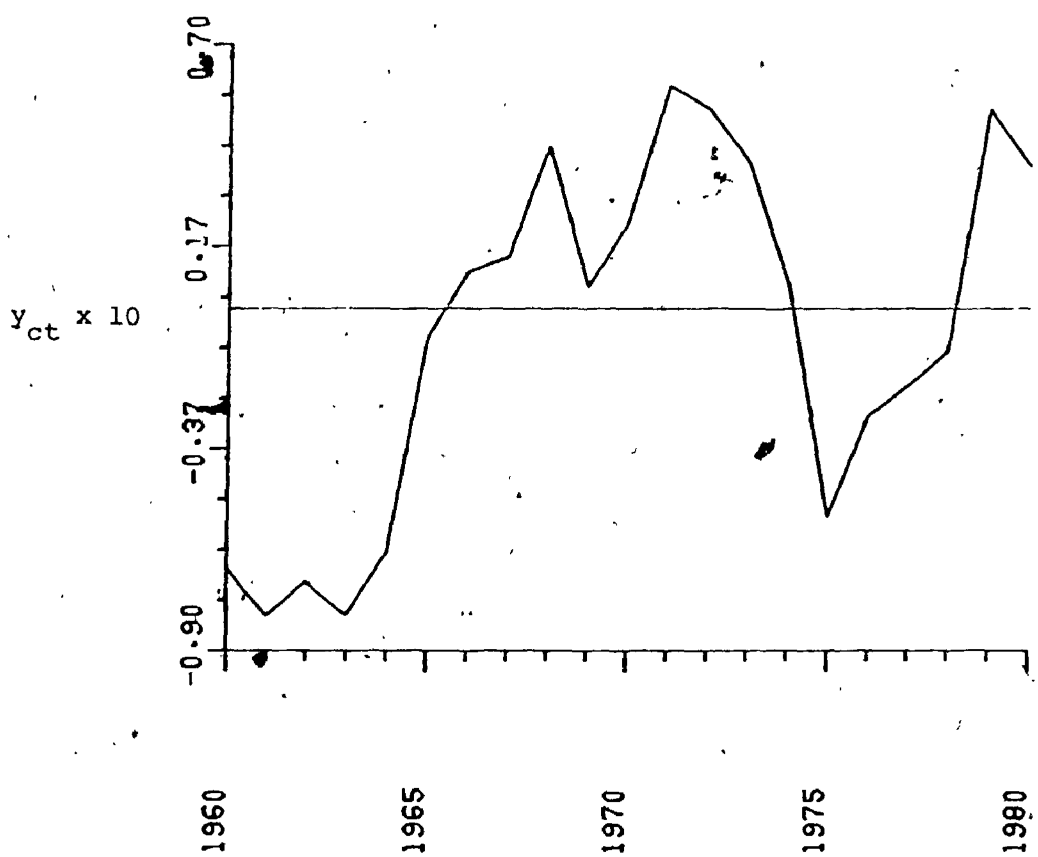


FIGURE 22

JAMAICA
TERMS OF TRADE

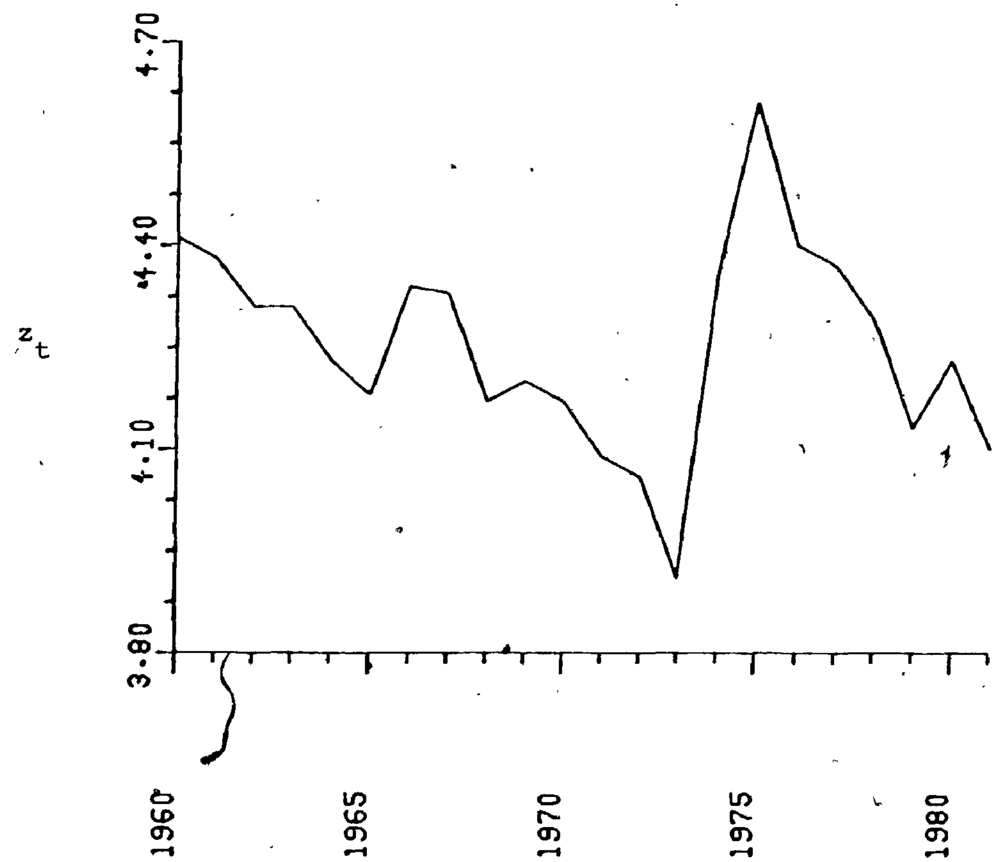


FIGURE 23

JAMAICA
TERMS OF TRADE SURPRISE

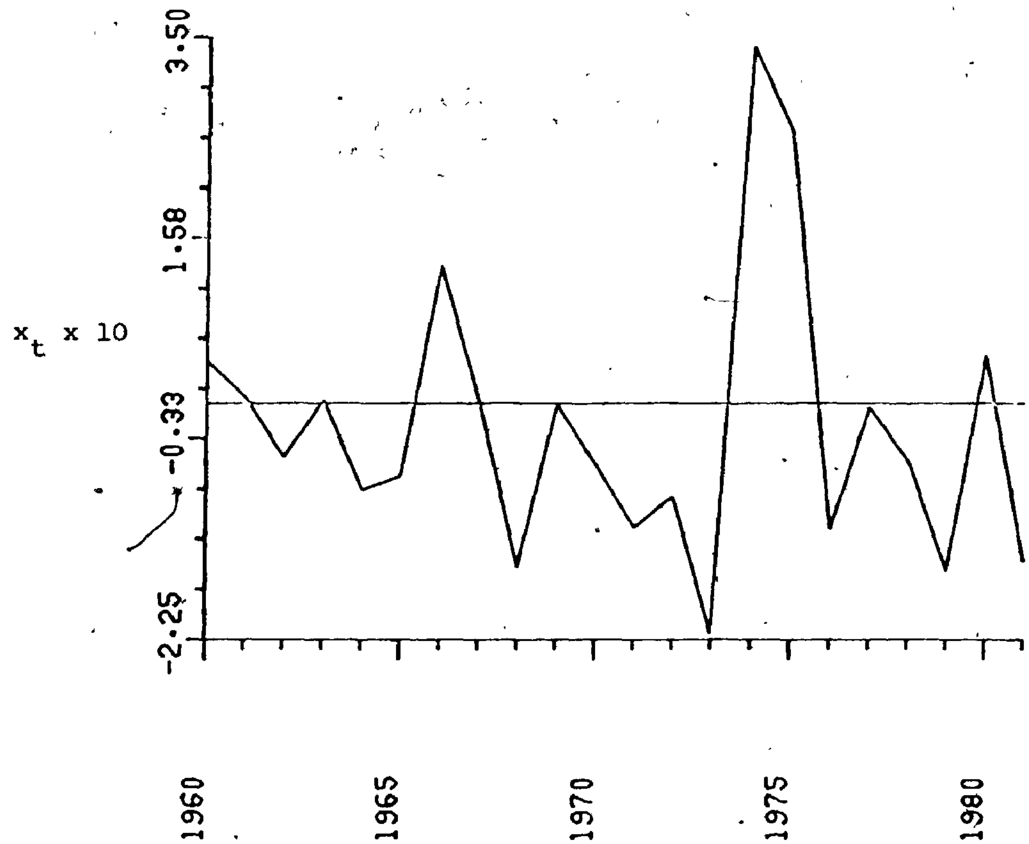


FIGURE 24

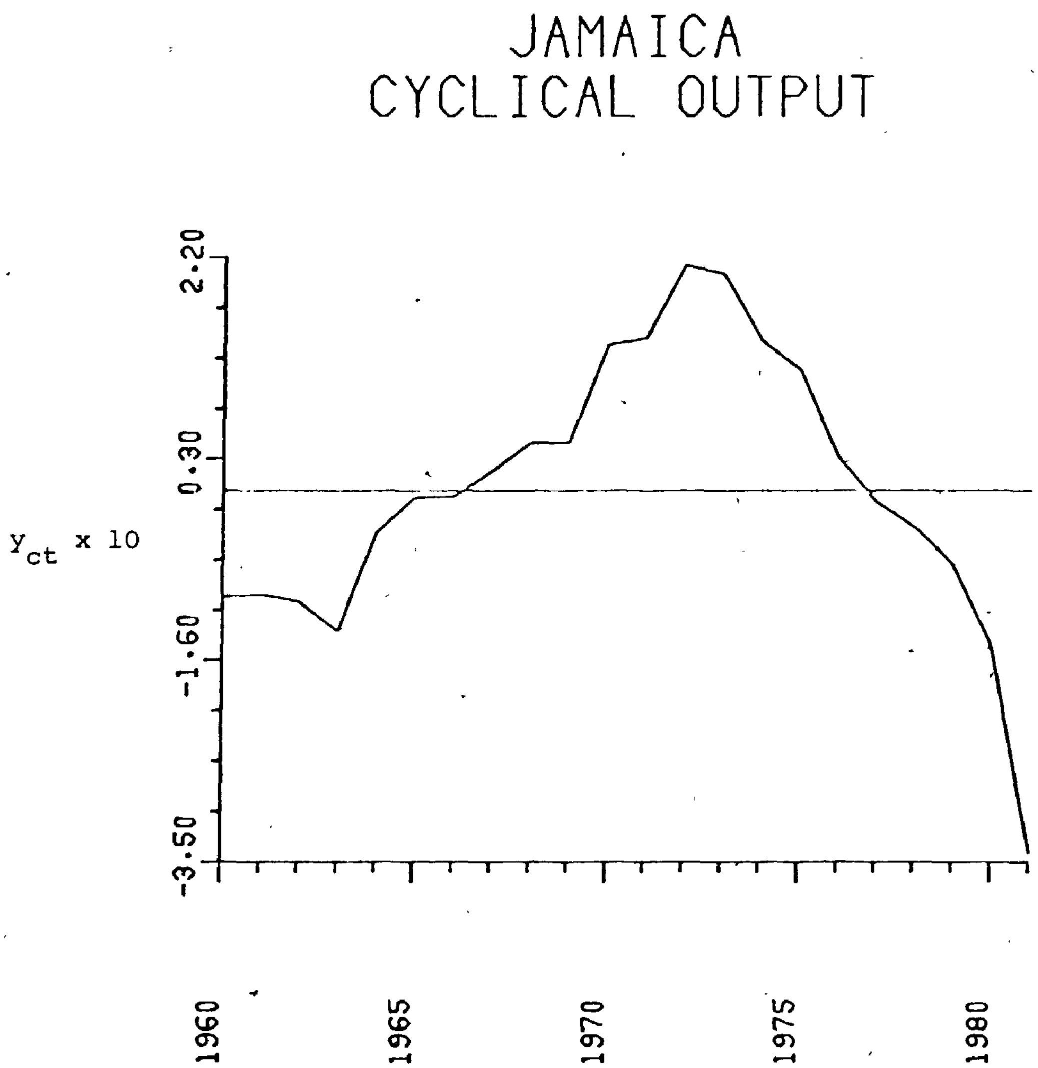

JAMAICA
CYCLICAL OUTPUT
2.20
0.30
-1.60
-3.50
y_{ct} x 10
1960
1965
1970
1975
1980

FIGURE 25

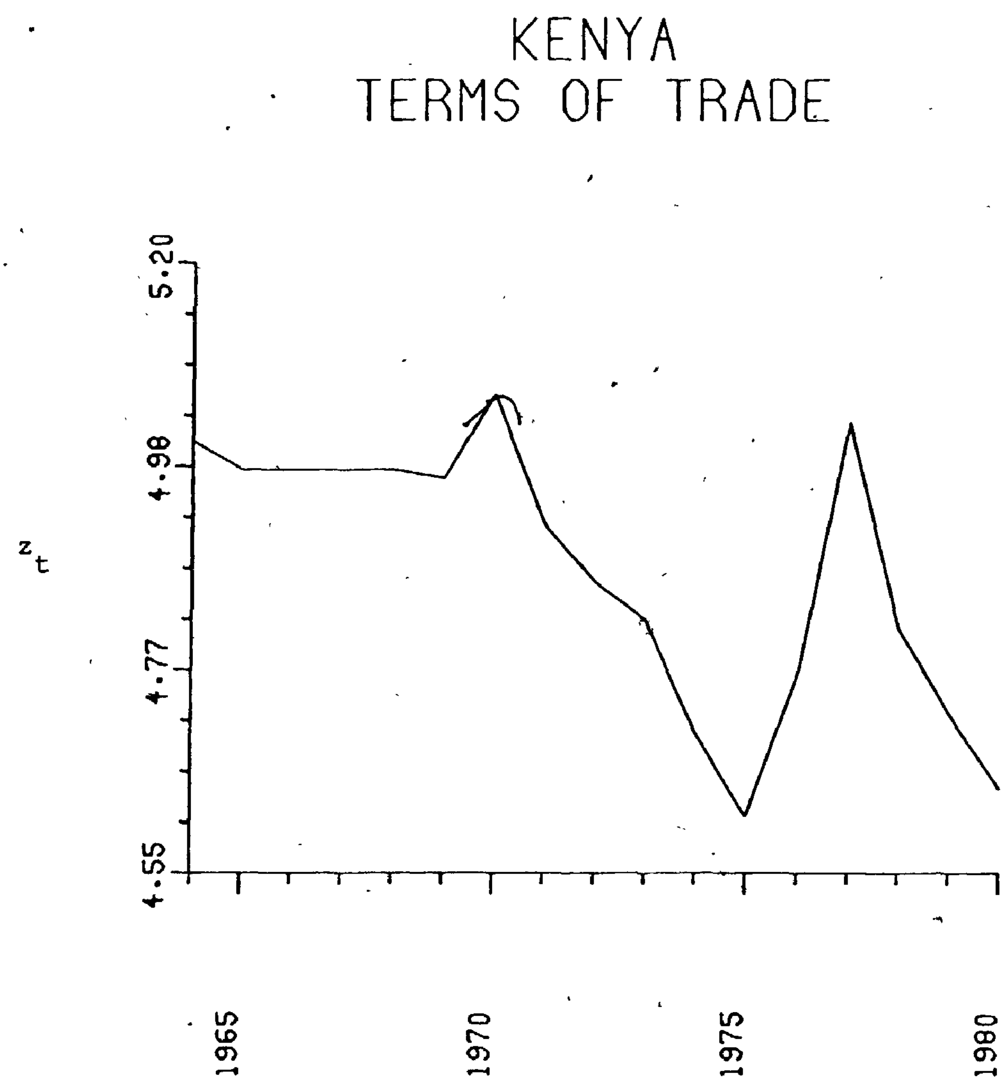


FIGURE 26

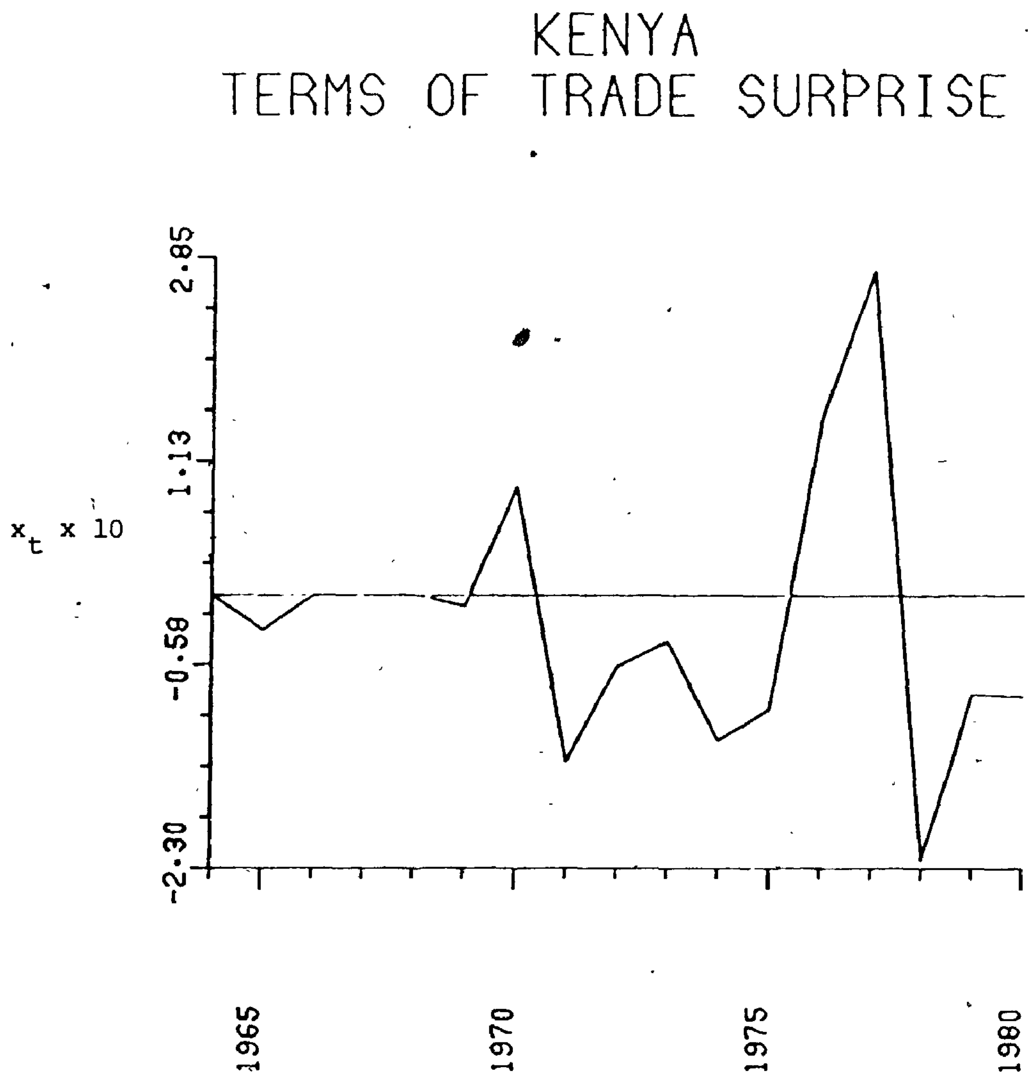

KENYA
TERMS OF TRADE SURPRISE
x_t x 10
2.85
1.13
-0.58
-2.30
1965
1970
1975
1980

FIGURE 27

KENYA
CYCLICAL OUTPUT

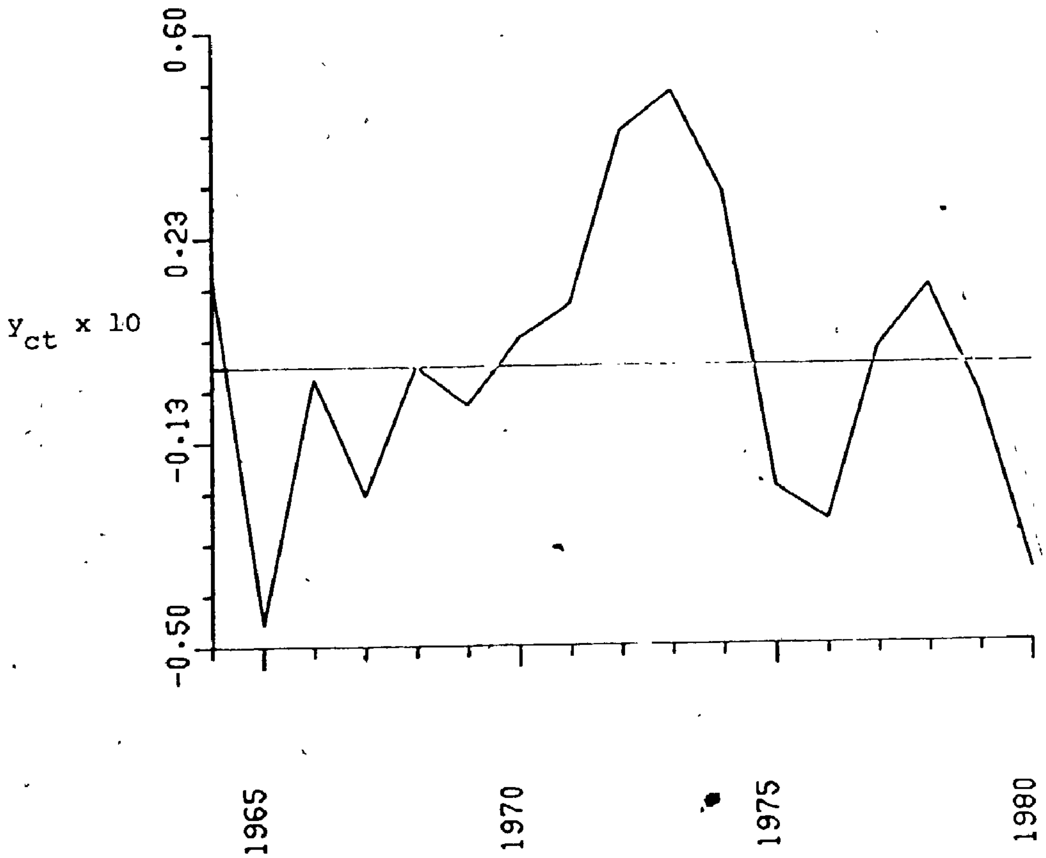


FIGURE 28

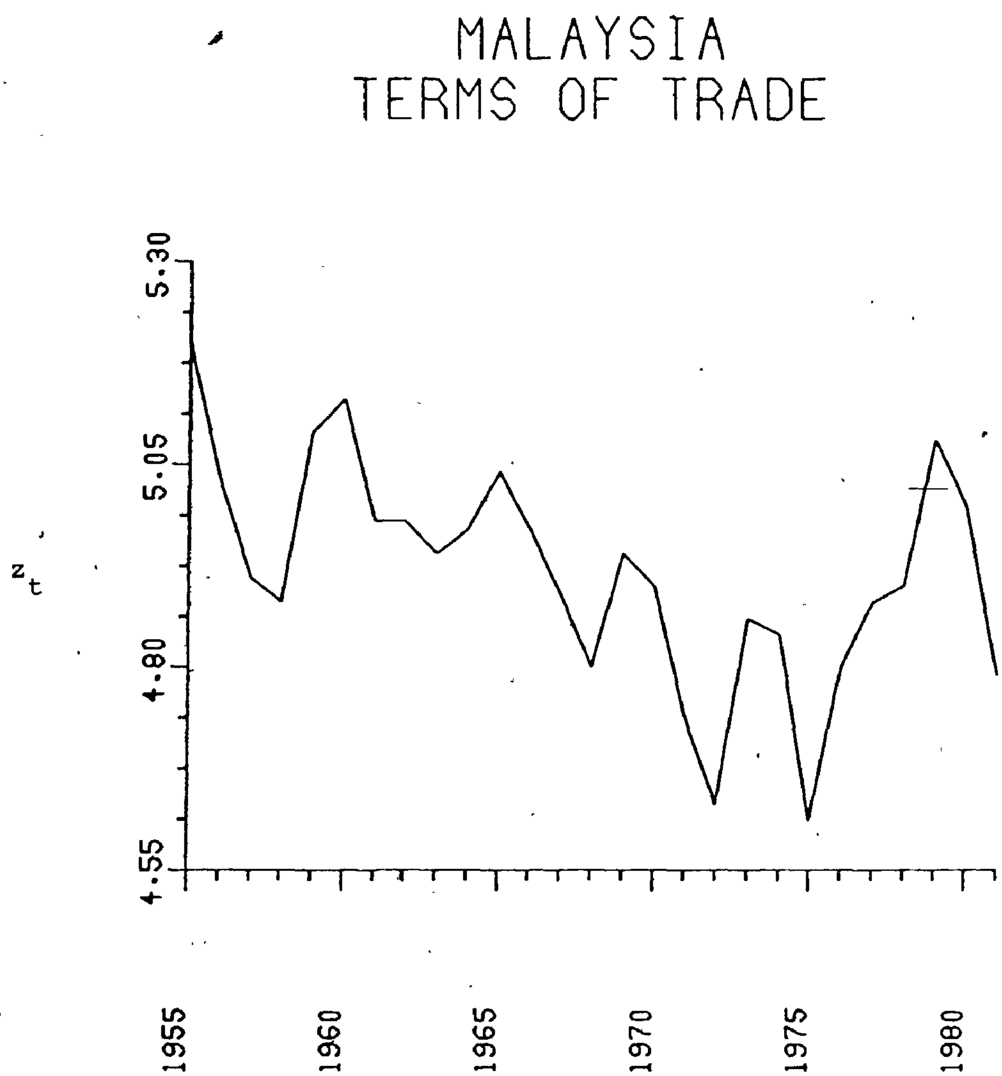

MALAYSIA
TERMS OF TRADE
5.30
5.05
4.80
4.55
z_t
1955
1960
1965
1970
1975
1980

FIGURE 29

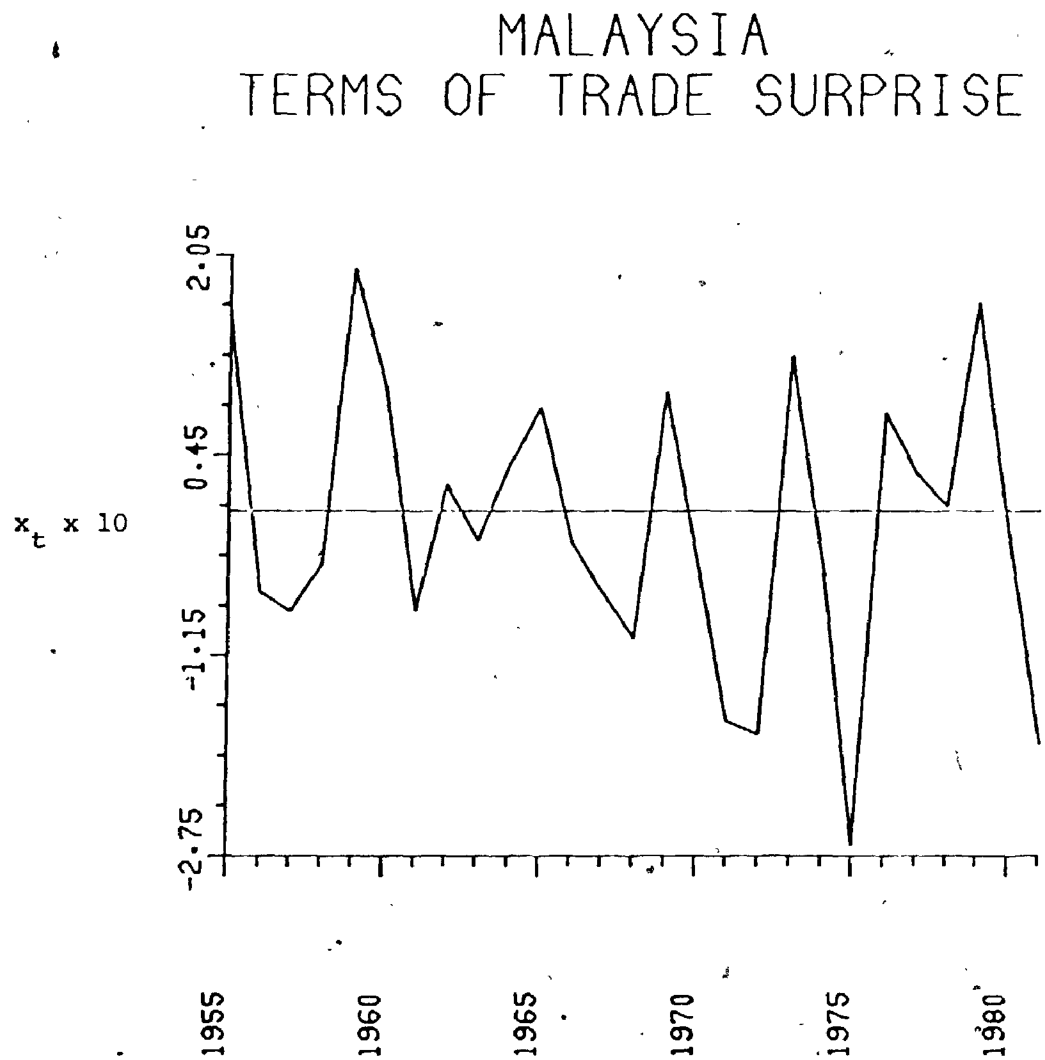

MALAYSIA
TERMS OF TRADE SURPRISE
2.05
0.45
-1.15
-2.75
x_t x 10
1955
1960
1965
1970
1975
1980

FIGURE 30

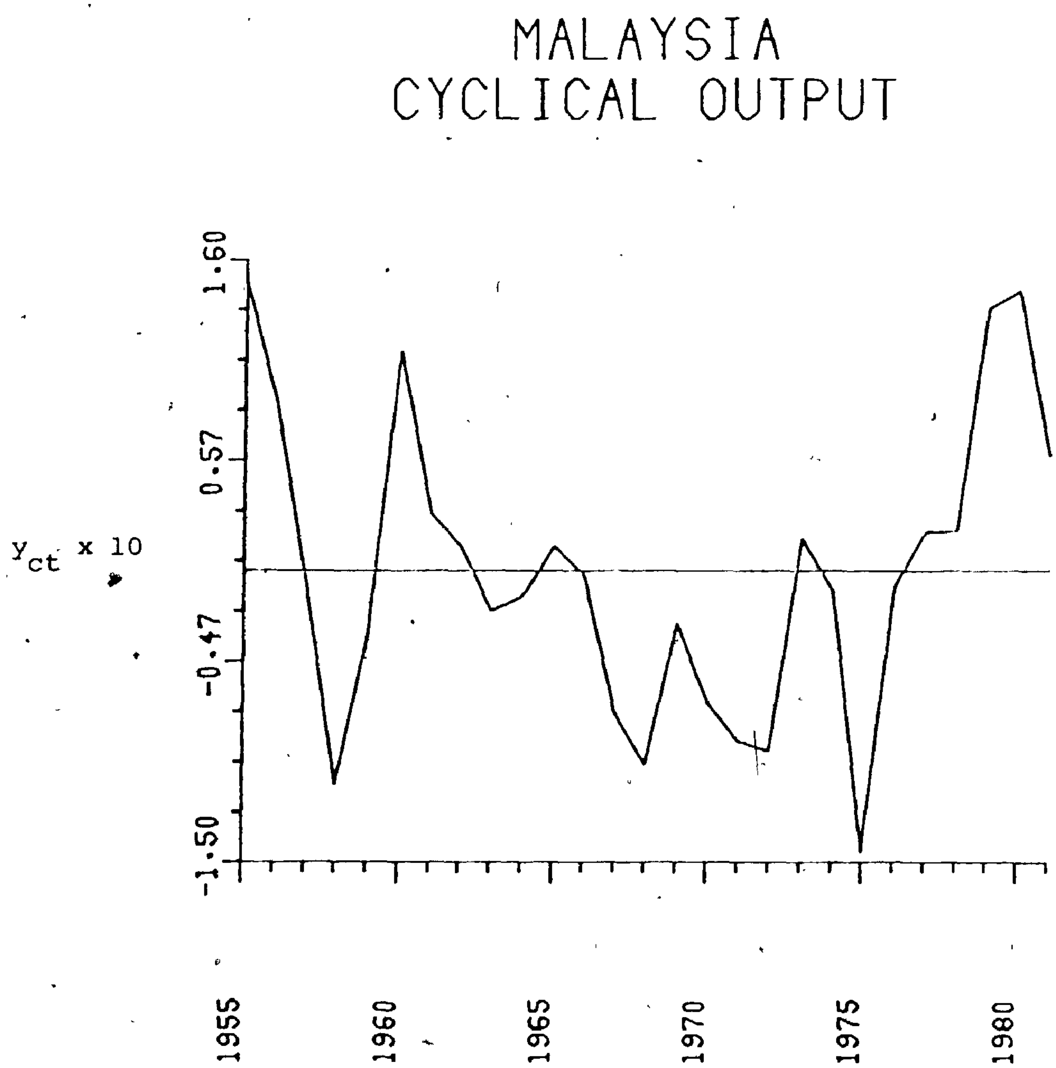

MALAYSIA
CYCLICAL OUTPUT
y_{ct} x 10
1.60
0.57
-0.47
-1.50
1955
1960
1965
1970
1975
1980

FIGURE 31

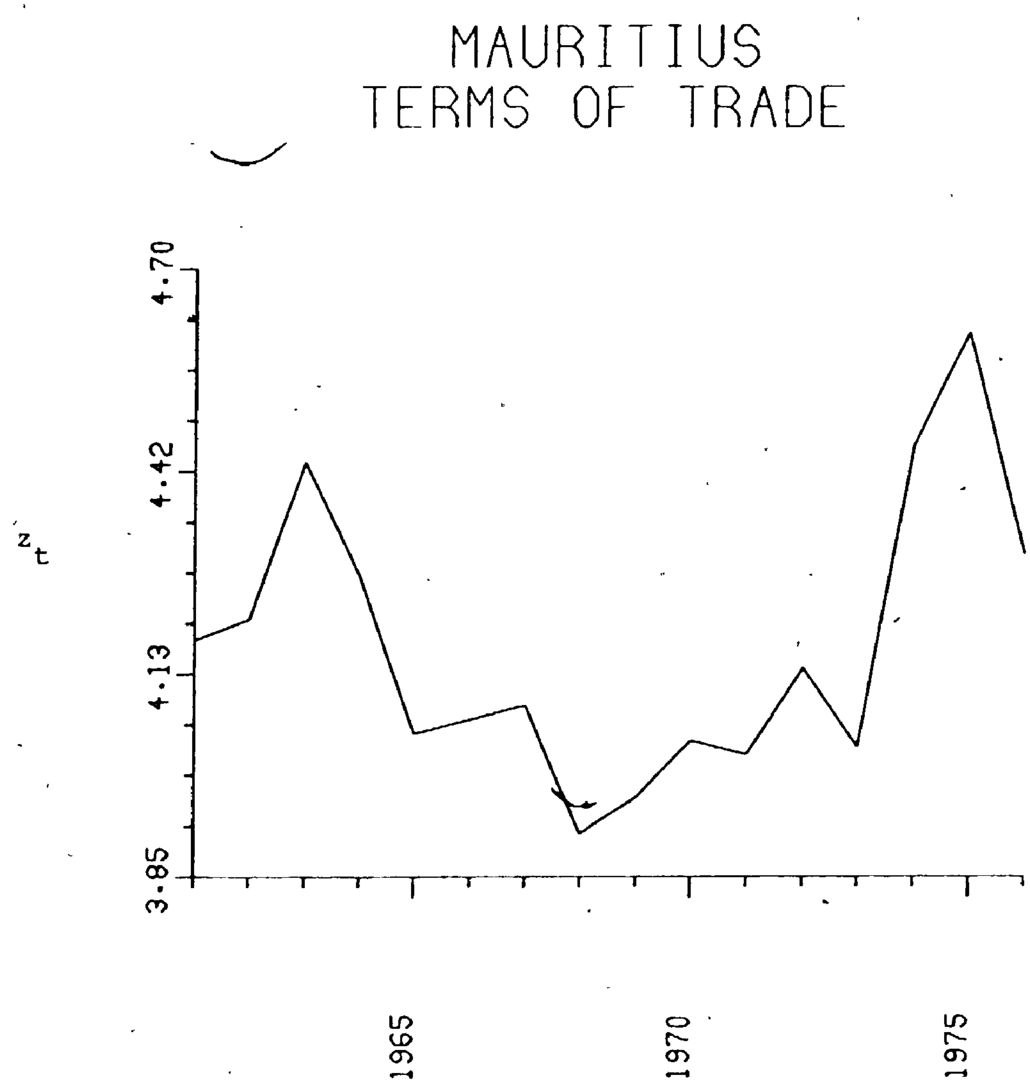


FIGURE 32

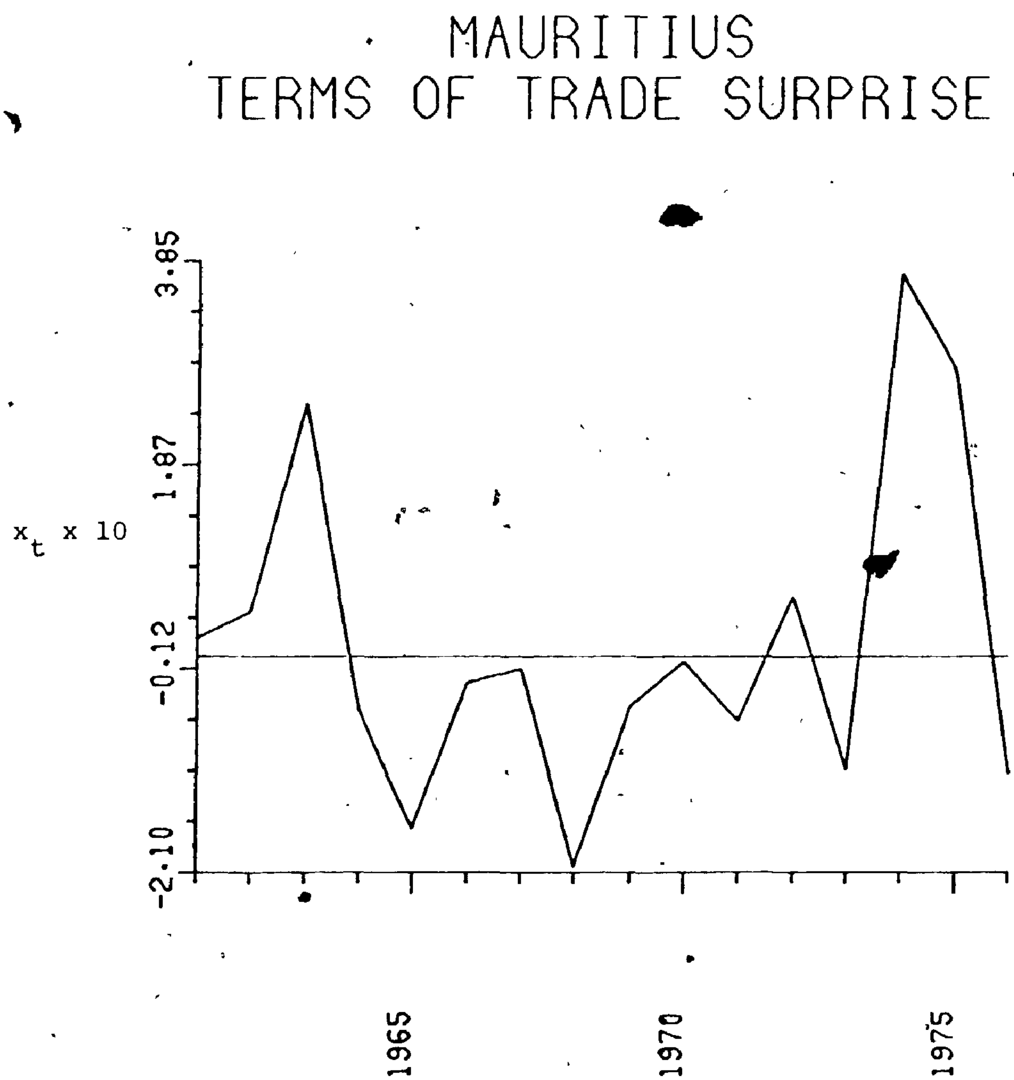

MAURITIUS
TERMS OF TRADE SURPRISE
3.85
1.87
-0.12
-2.10
x_t x 10
1965
1970
1975

FIGURE 33

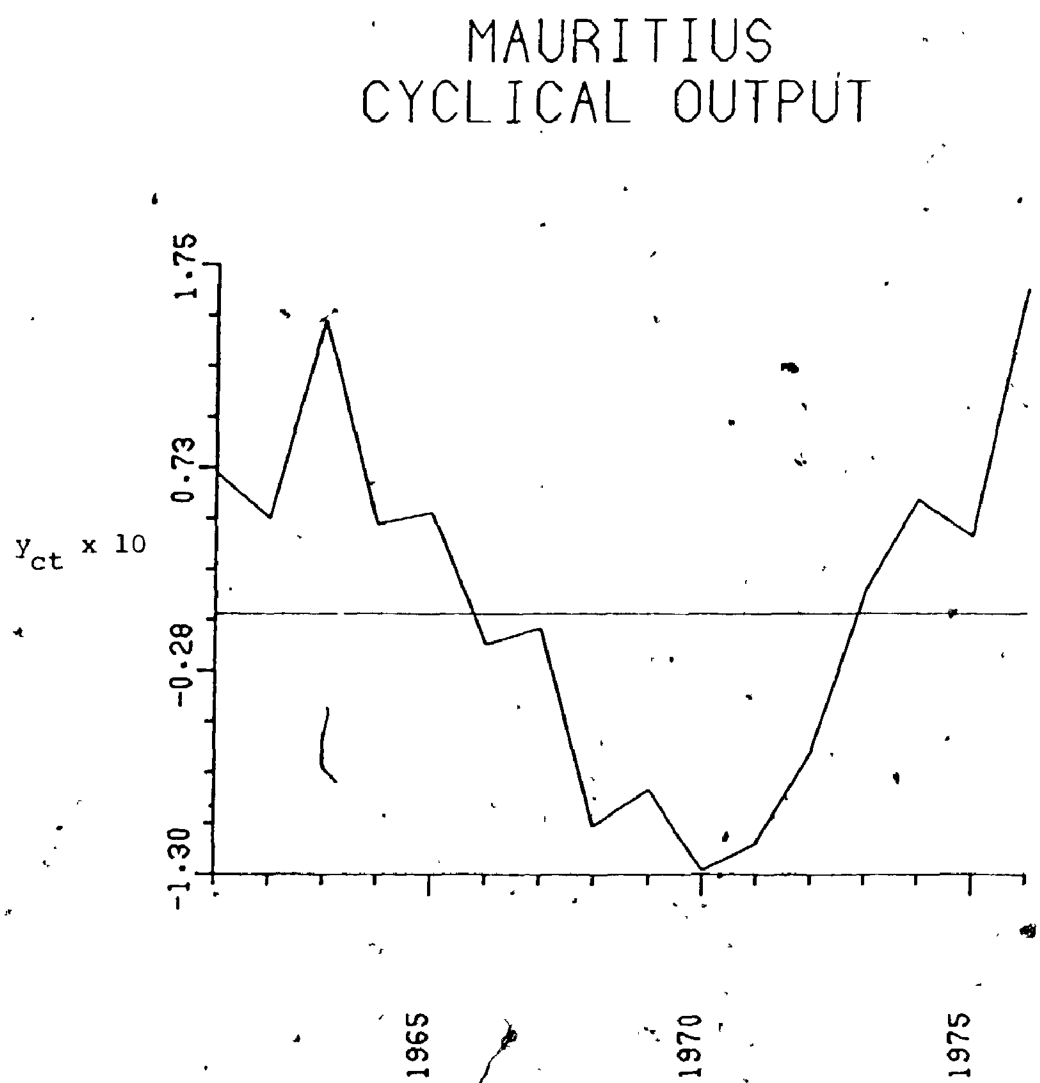

MAURITIUS
CYCLICAL OUTPUT
1.75
0.73
-0.28
-1.30
y_{ct} x 10
1965
1970
1975

FIGURE 34

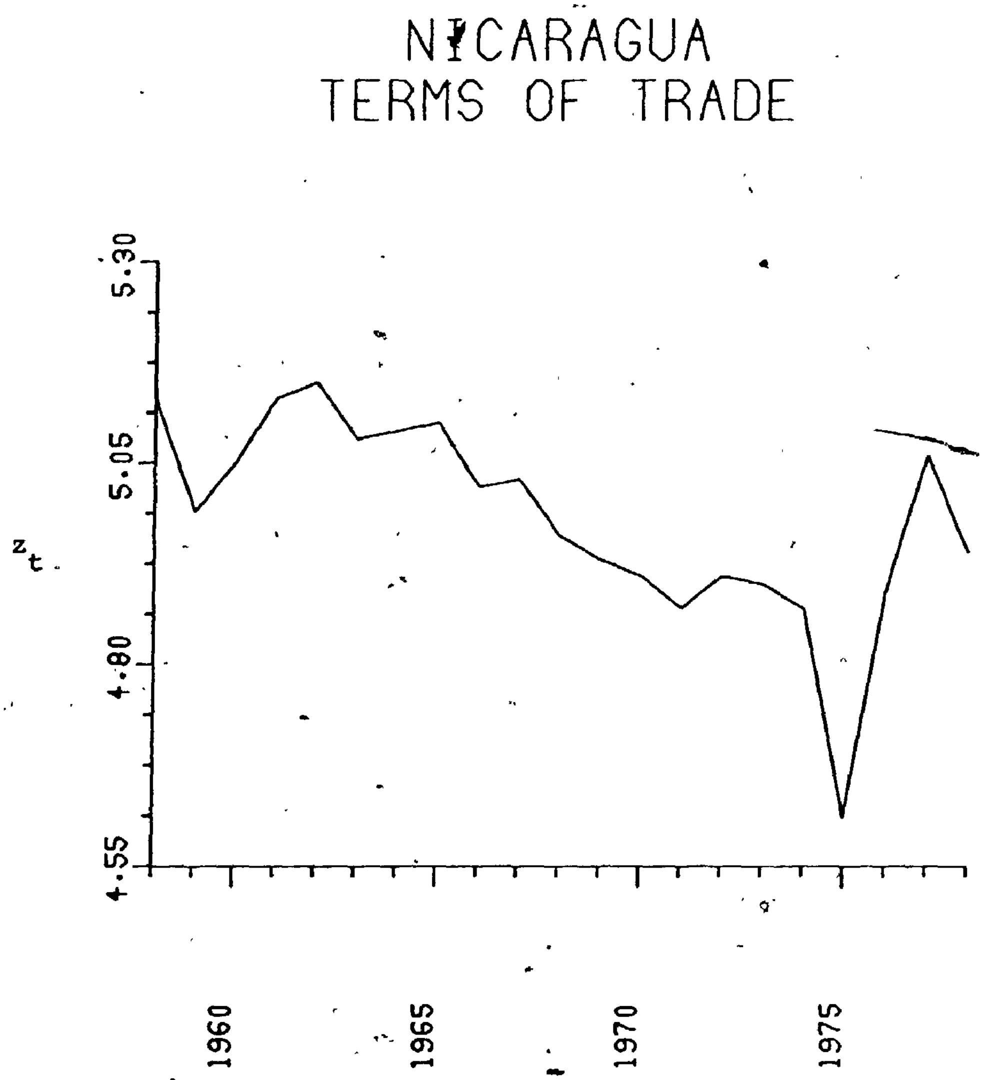

NICARAGUA
TERMS OF TRADE
5.30
5.05
4.80
4.55
z_t
1960
1965
1970
1975

FIGURE 35

NICARAGUA
TERMS OF TRADE SURPRISE

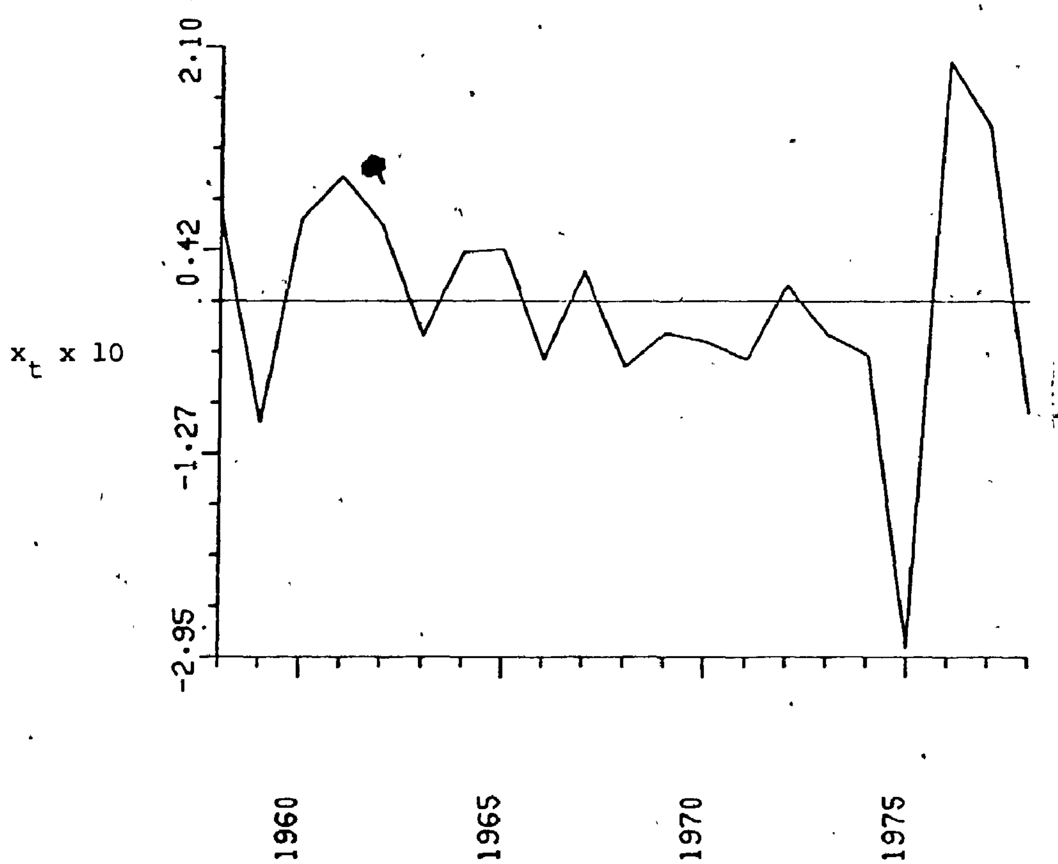


FIGURE 36

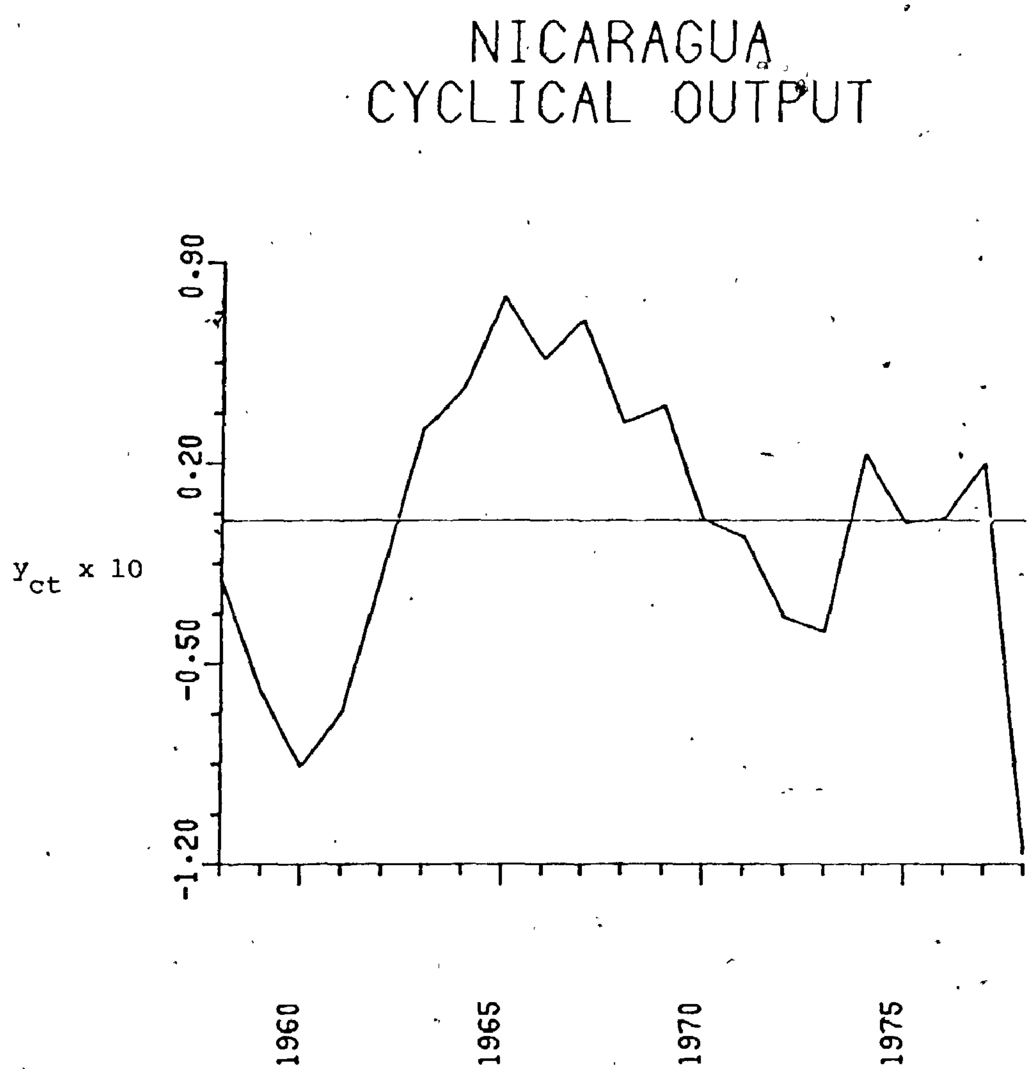

NICARAGUA
CYCLICAL OUTPUT
0.90
0.20
-0.50
-1.20
y_{ct} x 10
1960
1965
1970
1975

FIGURE 37

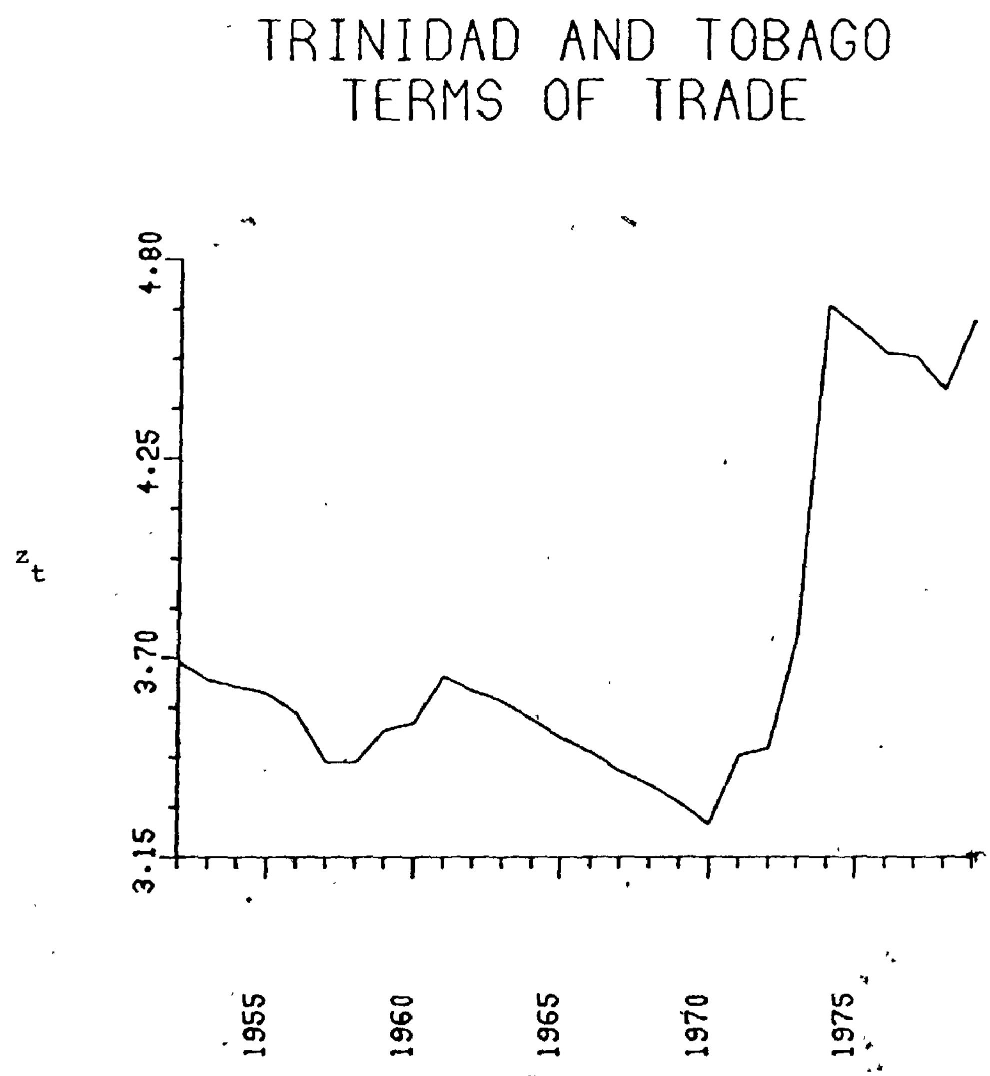

TRINIDAD AND TOBAGO
TERMS OF TRADE
4.80
4.25
3.70
3.15
z_t
1955
1960
1965
1970
1975

FIGURE 38

TRINIDAD AND TOBAGO TERMS OF TRADE SURPRISE

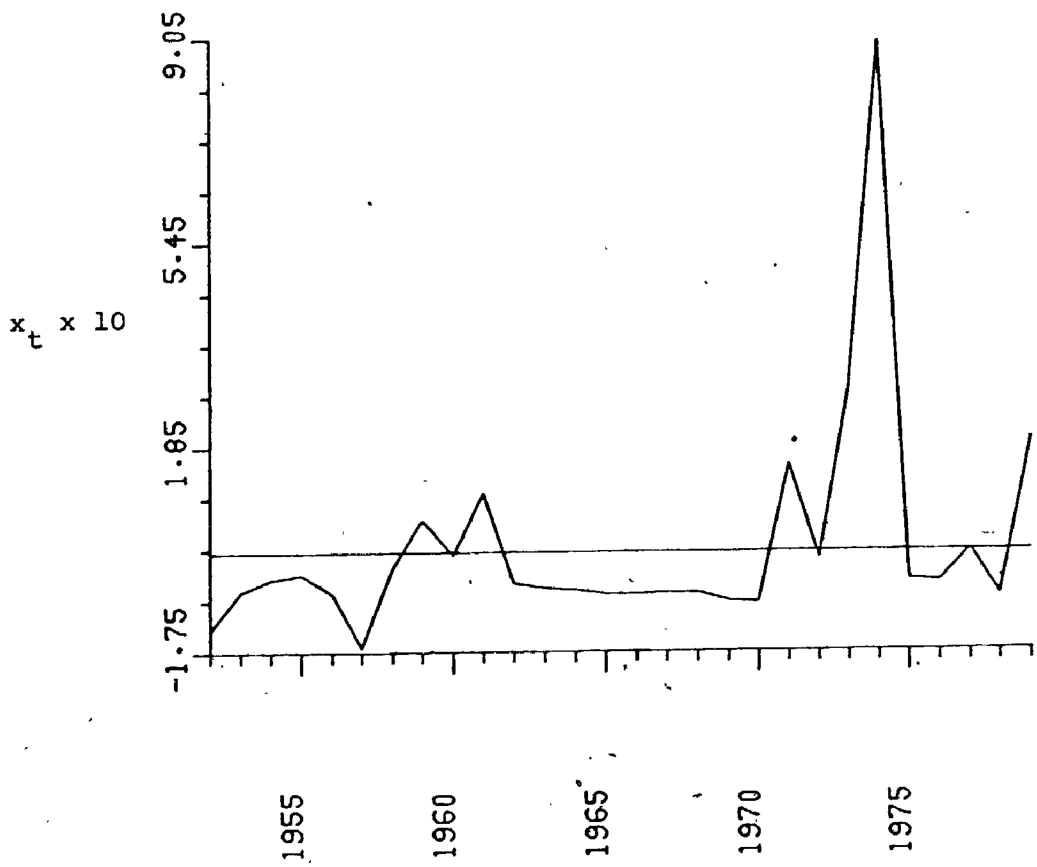


FIGURE 39

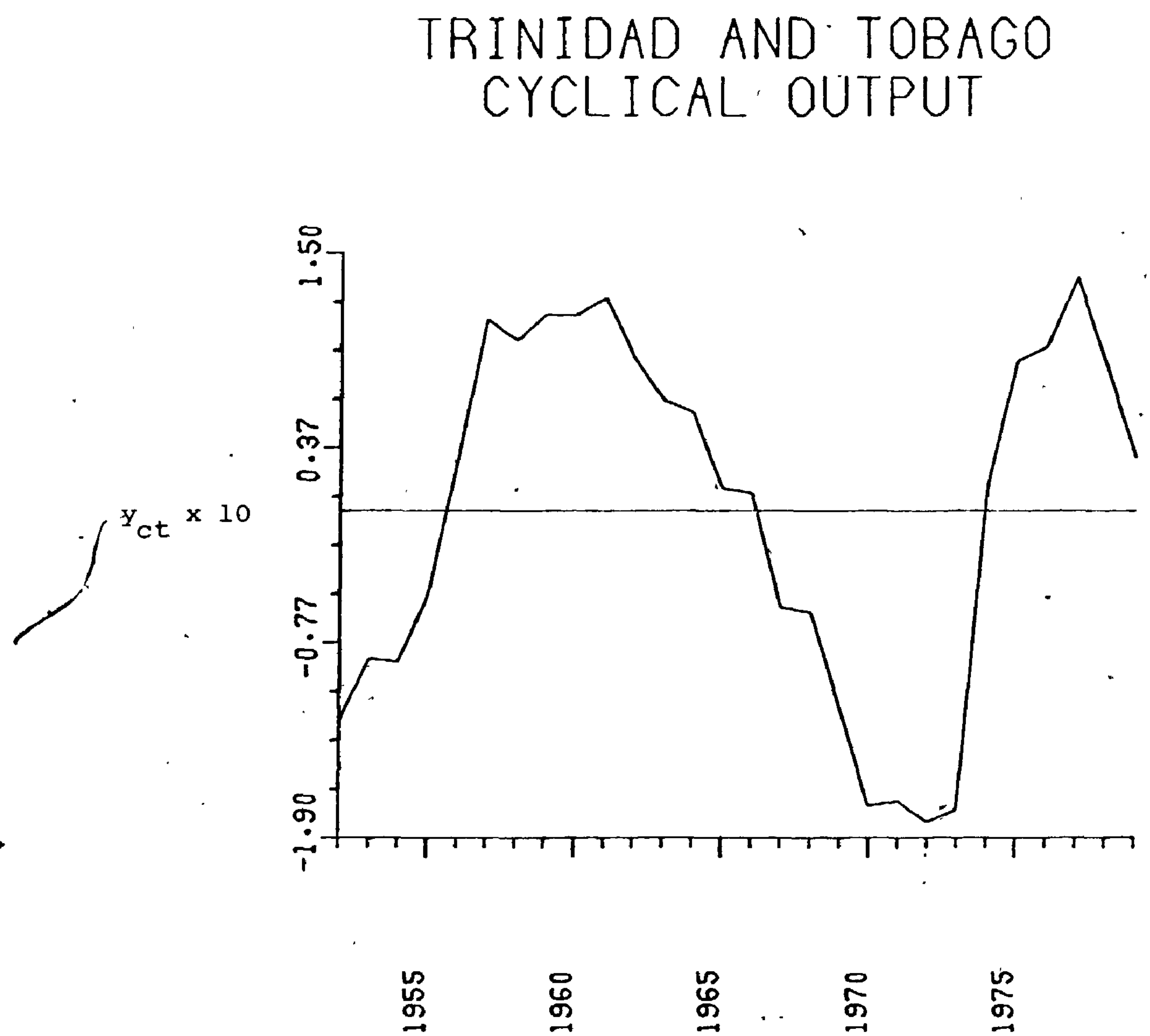

TRINIDAD AND TOBAGO
CYCLICAL OUTPUT
y_{ct} x 10
1.50
0.37
-0.77
-1.90
1955
1960
1965
1970
1975

FIGURE 40

ZAMBIA
TERMS OF TRADE

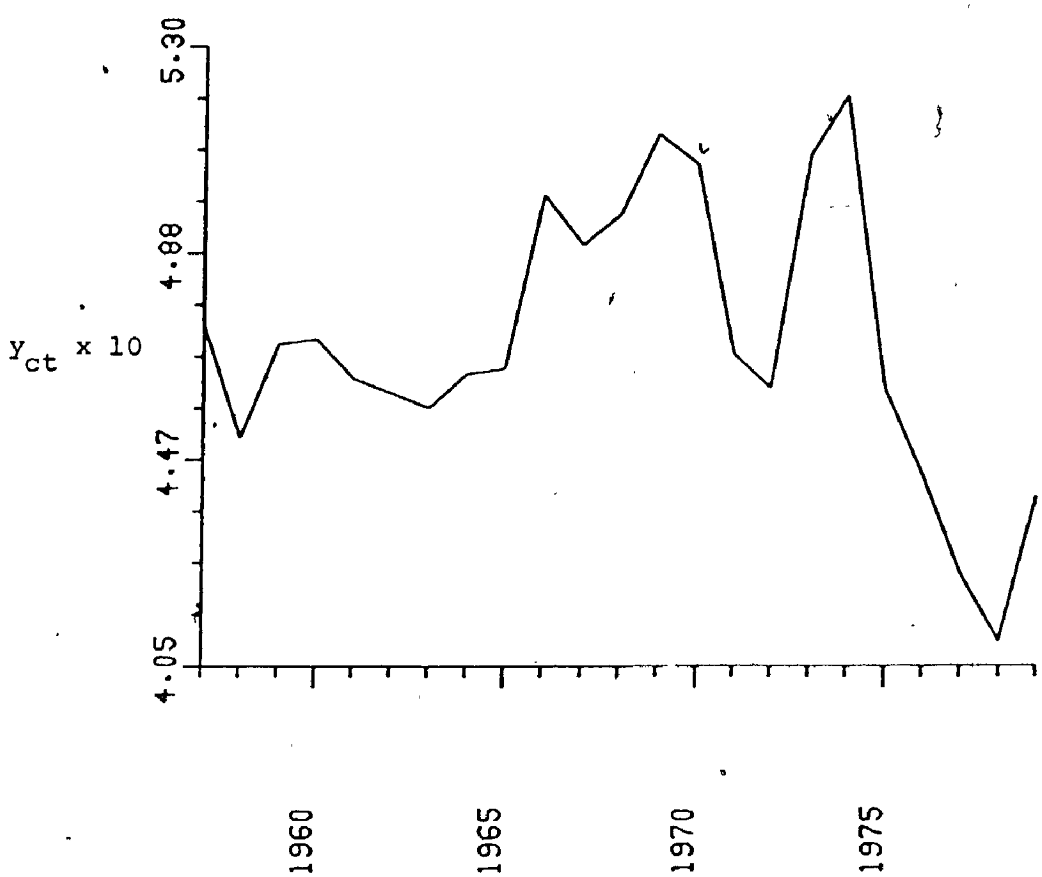


FIGURE 41

ZAMBIA
TERMS OF TRADE SURPRISE

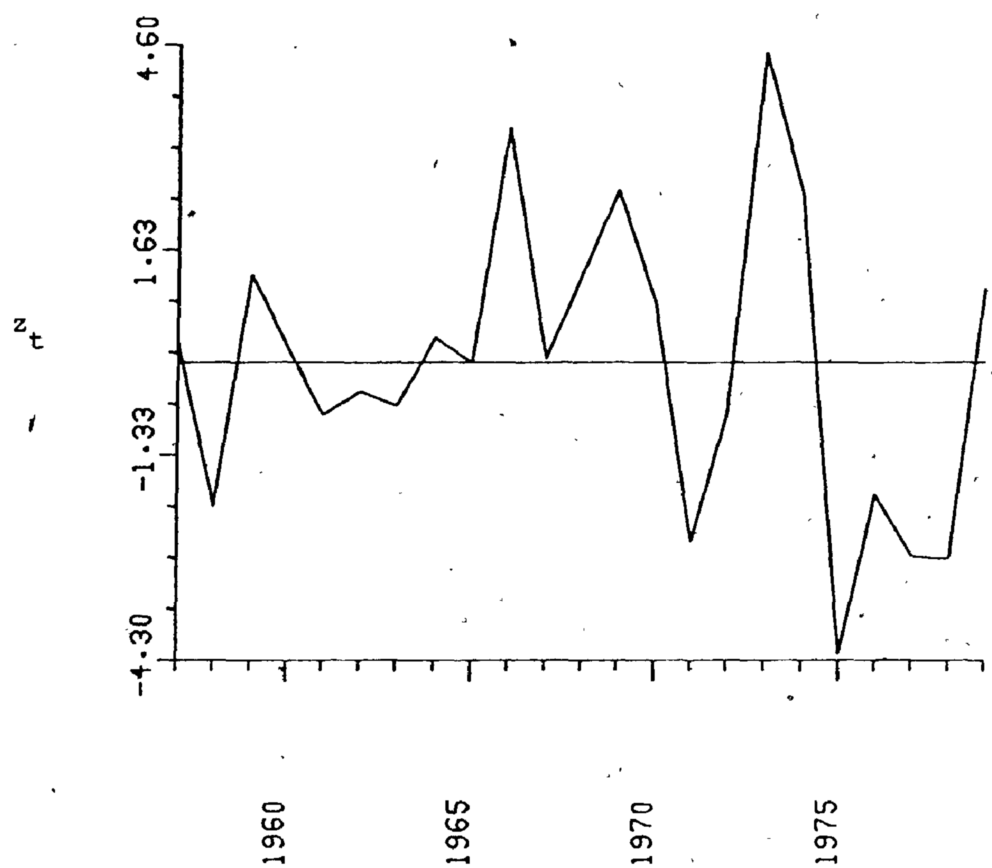
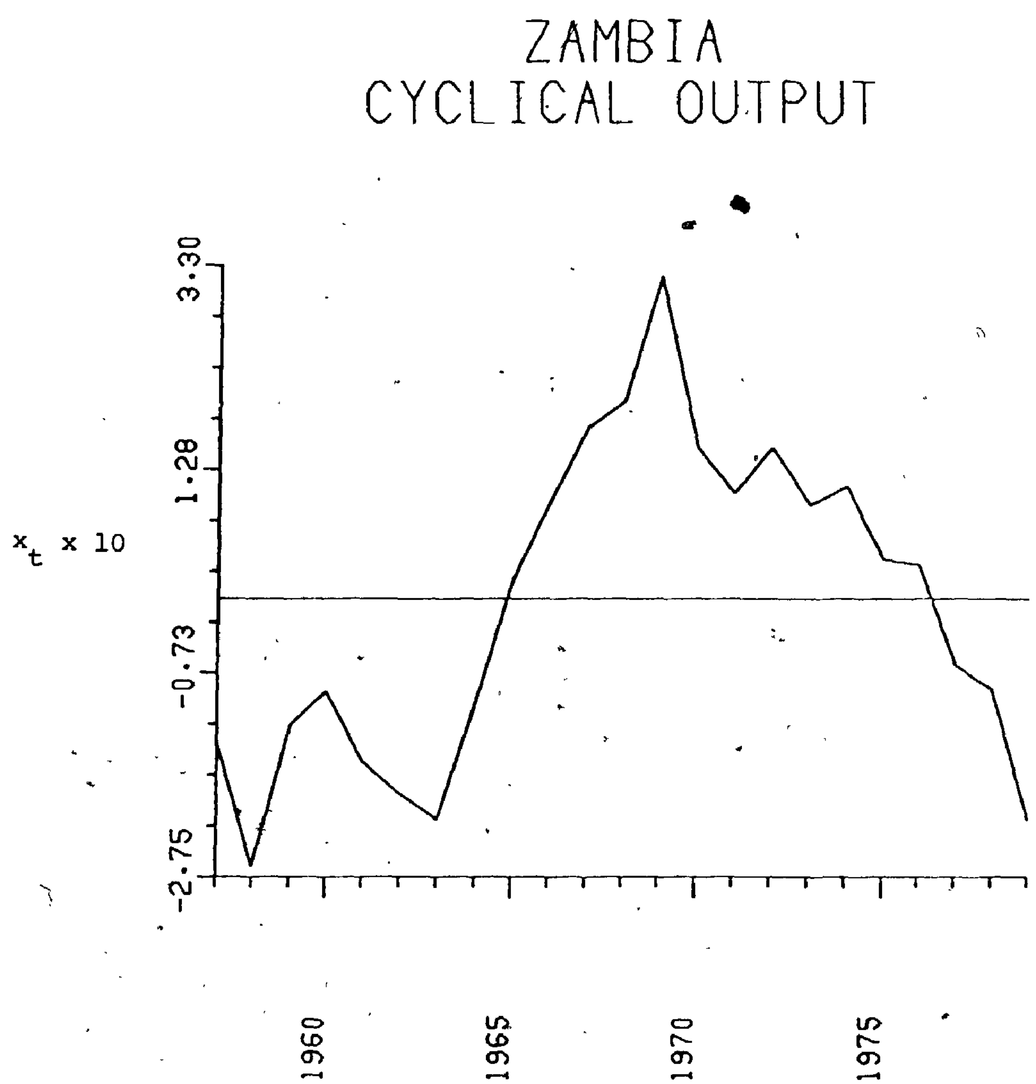


FIGURE 42


ZAMBIA
CYCLICAL OUTPUT
3.30
1.28
-0.73
-2.75
x_t x 10
1960
1965
1970
1975

B.3 THE DATA

Notation	Definition
P_t^*	World price level at time t, 1975=100
Z_t	Terms of trade (country specific) at time t, 1975=100
Y_t	Output (country specific) in constant 1975 U.S. dollars

THE WORLD PRICE LEVEL

Year	P_t^*
1950	28.7
51	31.4
52	32.7
53	33.2
54	33.6
1955	33.9
56	35.1
57	36.4
58	38.0
59	39.3
1960	40.3
61	41.3
62	42.8
63	44.5
64	46.5
1965	48.8
66	51.2
67	53.4
68	55.7
69	58.6
1970	62.1
71	65.7
72	69.5
73	76.1
74	87.9
1975	100.0
76	111.0
77	123.0
78	135.0
79	151.0
1980	174.0
81	198.0

Year	Costa Rica Z_t	Costa Rica Y_t	Dominican Republic Z_t	Dominican Republic Y_t	Fiji Z_t	Fiji Y_t	The Gambia Z_t	The Gambia Y_t	Guyana Z_t	Guyana Y_t
1950				846.6					54.9	
51				947.7					52.4	
52				1023.0					62.1	
53				1010.1					65.4	
54				1068.8			145.8		63.4	
1955				1135.0			126.8		62.5	
56				1248.9			133.9		65.7	188.0
57	248.8			1327.8			126.4		71.7	197.6
58	198.7			1397.7			97.4		67.0	186.0
59	180.9			1406.8			104.3		65.6	186.4
1960	164.7	816.2	54.9	1424.4	58.8	233.9	111.7		53.0	224.3
61	151.2	804.8	56.2	1392.5	63.5	252.2	106.5	52.1	56.8	243.2
62	150.6	870.4	63.9	1629.5	61.5	268.1	91.1	50.4	55.2	246.4
63	150.0	912.0	69.2	1752.2	72.2	301.5	87.6	49.0	69.0	216.7
64	149.3	949.8	71.6	1823.9	75.3	315.4	90.3	56.7	63.8	239.2
1965	140.1	1043.3	62.5	1625.5	58.2	307.4	96.3	62.4	51.0	252.8
66	130.4	1125.3	66.6	1838.6	61.3	316.1	82.0	69.4	50.7	265.6
67	119.8	1188.9	66.3	1901.0	51.6	347.4	78.7	75.3	44.9	282.4
68	108.1	1289.7	72.4	1910.3	50.1	321.5	65.8	58.4	46.3	295.8
69	105.0	1360.4	76.5	2143.5	54.2	338.9	78.2	69.3	51.2	317.0
1970	115.7	1462.5	69.9	2335.8	55.5	391.6	80.5	74.8	50.6	328.9
71	100.0	1561.7	62.6	2589.8	54.0	406.0	82.4	72.3	50.6	343.0
72	99.0	1689.4	63.9	2859.0	64.2	459.4	76.7	88.9	58.9	347.0
73	112.0	1819.7	63.7	3227.7	65.2	534.5	111.7	83.9	56.7	346.6
74	103.3	1920.5	68.8	3421.4	82.5	618.4	183.2	110.8	90.4	437.7
1975	100.0	1960.9	100.0	3599.1	100.0	683.3	100.0	96.3	100.0	504.9
76	125.1	2069.1	65.8	3841.3	78.2	680.0	72.1	131.5	88.4	435.7
77	173.9	2253.3	65.4	2564.5	76.3	669.5	86.5	149.6	92.3	405.0
78	135.1	2394.6	54.3	2619.5	80.3	671.7	103.7	139.5	75.5	396.1
79	125.9	2513.0	48.5	2741.6	69.3	760.2	74.5	147.6	73.6	349.0
1980	122.4	2544.1	50.0	2899.6	83.0		60.8	136.0	86.1	350.7
81	95.3		66.8				66.6	135.5		

	Honduras		Jamaica		Kenya		Malaysia		Mauritius	
Year	Z_t	Y_t	Z_t	Y_t	Z_t	Y_t	Z_t	Y_t	Z_t	Y_t
1950		457.5								
51		478.0								
52		478.0								
53		507.0								
54		476.0	87.1		193.5					
1955		504.0	90.1		193.7		180.5	3294.2		
56		526.5	90.7		172.7		153.5	3307.7		
57		548.5	97.7		161.7		136.3	3219.4		
58		579.0	87.1		154.5		131.2	3103.0		
59		592.5	81.0		160.6		162.2	3584.8		
1960	145.3	591.5	82.1	1683.4	155.8		169.2	4434.5		340.9
61	156.9	608.0	80.1	1723.0	161.2		145.1	4356.6	65.3	418.4
62	167.0	639.0	74.3	1747.6	153.1		145.4	4583.7	67.5	421.9
63	157.6	660.0	74.4	1736.6	150.0		139.2	4734.1	84.2	480.4
64	164.0	699.0	68.4	1950.1	150.0	1748.4	143.9	5098.0	71.2	447.4
1965	155.0	771.0	65.2	2059.1	145.7	1743.4	154.0	5592.3	57.5	464.4
66	150.5	816.5	77.1	2105.8	145.7	1934.0	144.4	5891.1	58.4	448.8
67	151.1	854.5	76.3	2204.0	145.7	2010.0	133.1	5864.4	59.8	466.5
68	147.7	916.5	64.6	2309.9	145.7	2182.9	121.8	6104.8	50.0	435.8
69	142.2	919.5	67.0	2360.4	144.4	2303.3	140.1	7017.9	52.7	457.9
1970	152.7	974.0	65.0	2643.1	158.3	2473.3	134.2	7199.6	56.7	453.9
71	141.5	1052.5	59.8	2723.1	137.5	2642.7	114.5	7544.7	55.9	474.3
72	136.7	1089.5	58.1	2975.2	129.5	2892.9	102.5	8023.3	62.6	512.5
73	129.2	1119.5	49.9	3018.2	124.5	3094.6	129.2	9566.0	56.4	573.0
74	106.3	1129.0	78.5	2892.9	110.1	3227.0	126.7	9945.7	86.0	619.0
1975	100.0	1106.0	100.0	2875.7	100.0	3247.8	100.0	9299.0	100.0	626.8
76	133.4	1183.0	81.2	2701.6	116.2	3426.7	121.6	11398.2	73.9	731.1
77	184.6	1242.5	78.7	2649.9	152.8	3752.3	131.1	12526.9	66.1	
78	155.3	1305.5	73.2	2642.8	122.3	4029.8	134.1	13389.8	61.2	
79	123.1	1450.5	62.5	2604.7	112.6	4191.0	160.0	16058.6	59.3	
1980	114.8	1488.5	68.6	2464.1	103.4	4314.3	149.0	17326.8	56.1	
81		1492.5	60.2	2077.4			120.4	17002.6		

Year	Nicaragua Z_t	Nicaragua Y_t	Trinidad & Tobago Z_t	Trinidad & Tobago Y_t	Zambia Z_t	Zambia Y_t
1950		384.1				
51		410.0				
52		479.4	40.1	505.3		
53		491.1	38.3	558.0		888.9
54		536.8	37.2	592.8		960.4
1955		573.0	36.6	655.6		1134.5
56		572.5	34.8	756.2		1038.1
57		621.0	30.2	872.8	114.4	876.5
58	169.4	623.0	30.3	918.2	91.2	812.8
59	146.9	632.4	33.1	992.2	109.5	980.6
1960	156.3	649.7	33.7	1055.5	111.4	1063.0
61	169.5	699.0	38.5	1135.6	102.3	1039.7
62	173.0	774.5	37.1	1167.9	99.8	1055.2
63	160.3	859.4	35.7	1212.8	96.2	1078.6
64	162.3	919.1	34.2	1281.3	103.5	1269.7
1965	164.2	1001.4	32.6	1304.9	104.9	1502.8
66	151.2	1034.0	31.1	1386.1	148.7	1704.9
67	152.9	1106.8	29.8	1381.2	134.7	1922.4
68	142.5	1126.7	28.5	1464.9	142.6	2065.4
69	139.0	1196.3	27.1	1475.7	167.1	2450.8
1970	135.5	1212.1	25.6	1482.9	158.0	2171.1
71	130.9	1271.9	30.9	1584.6	107.7	2172.6
72	135.6	1304.9	31.4	1666.3	100.2	2385.5
73	133.8	1369.8	43.0	1785.5	160.9	2362.2
74	130.1	1538.6	106.9	2296.1	180.4	2522.3
1975	100.0	1584.2	100.0	2627.4	100.0	2460.1
76	133.5	1675.9	93.4	2819.0	84.8	2567.4
77	157.0	1802.5	92.5	3128.9	69.3	2436.8
78	139.9	1660.2	84.5	3164.1	60.2	2495.9
79	134.5		102.1	3189.6	80.9	2297.0
1980	120.2		145.4			2346.7
'81			148.8			

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